Livestock Predation and its Management in South Africa: A Scientific Assessment

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Chapter 6

PAST AND CURRENT MANAGEMENT OF PREDATION ON LIVESTOCK

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INTRODUCTION

The causes of human-predator conflict (HPC) are typically viewed from an anthropocentric perspective (see Redpath et al.*, 2013) and are consequently translated into costs incurred by humans through various animal behaviours (Aust, Boyle, Ferguson & Coulson, 2009; Barua, Bhagwat & Jadvav, 2013). Instances of HPC may originate where predators prey on livestock (Wang & Macdonald, 2006; Chaminuka, McCrindle & Udo, 2012), utilise resources of recreational value (Pederson* et al.*, 1999; Skonhoft, 2006), damage human property (Gunther* et al.*, 2004), pose a threat to the safety of humans (Loe & Roskaft, 2004; Thavarajah, 2008), or compete with other species of conservation or economic value (Engeman, Shwiff, Constantin, Stahl & Smith, 2002). In response, humans employ a range of management strategies to moderate the costs that they incur from HPC.*

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WHILE many predation management strategies have shown some success in reducing livestock losses (Linnell, Swenson & Andersen, 2001), negative consequences of predation management have also been demonstrated, including: (1) the extinction or near extinction of predators in certain areas because of eradication programmes (Woodroffe & Ginsberg, 1999; Treves & Karanth, 2003; Bauer & Van der Merwe, 2004; Skead, 2007; 2011; Chapter 2); (2) the alteration of ecosystems and apparent increases in the numbers of some primary consumers and/or meso-predators where predators were excluded or eradicated (Estes, 1996; Ripple *et al.*, 2014; Chapter 8); (3) threats to populations of non-target species because of non-specific management techniques (Glen, Gentle & Dickman, 2007; also see "Predation management methods"); (4) counterproductive predation management approaches, with more livestock losses occurring after their implementation (Allen, 2014; Treves, Krofel & McManus, 2016); and (5) the straining of relationships between livestock producers, different sectors of society and policy makers (Madden, 2004; Thompson, Aslin, Ecker, Please & Tresrail, 2013; Chapter 4).

However, without predation management, the economic viability of livestock farms may be threatened and this can negatively affect local and regional economies (Jones, 2004; Feldman, 2007; Strauss, 2009; Allen & West, 2013; Chapter 3). In South Africa, approximately 80% of land area is used for livestock farming (Meissner, Scholtz & Palmer, 2013). The country is also a signatory to a number of global commitments to biodiversity conservation (Chapter 5). Thus, it is important to implement predation management strategies that ensure both a sustainable livestock industry and promote biodiversity and ecosystem conservation (Avenant & Du Plessis, 2008). It is also important to account for the religious and cultural norms of the specific area where predation management is applied (Thirgood & Redpath, 2008; Dickman, 2010).

In this chapter, we assess the various predation management methods used in South Africa and internationally and consider their application in the South African context. We focus on the effectiveness of each method.

PREDATION AND PREDATION MANAGEMENT APPROACHES USED INTERNATIONALLY

Predation management strategies around the world have similar broad objectives but vary markedly at the level of implementation because they are governed by different economic, political and legal frameworks and occur in different ecological and cultural settings. Where predation management is used to protect livestock, the livestock production setting and scales of operation can also vary enormously. At a global level, three broad predation management strategies are used: eradication or exclusion, regulated harvest or suppression, and preservation or coexistence (Treves & Karanth, 2003). The relative reliance on each strategy varies in accordance with governance structures or what is mandated by specific laws. In addition, this reliance is also influenced by the complex and constantly shifting interplay of various factors including cost effectiveness, practicality, feasibility, environmental consequences and social acceptance at both local and national scales.

Predator management in many parts of the world was originally used as a means to ensure continued hunting opportunities in conjunction with reduced predation of livestock. Not surprisingly, early attitudes of wildlife managers and policies focused on predator control (e.g. Beinart, 1998; Stubbs, 2001; Feldman, 2007; Chapter 2). State sponsored eradication of predators and harvesting through hunting has, however, declined in many parts of the world due to increasing pressure from animal welfare organisations and conservationists (Zinn, Manfredo, Vaske & Wittman, 1998). Simultaneously, non-lethal methods linked to conservation strategies have gained favour in some areas, despite the complexity and costs associated with their implementation. Wildlife managers are increasingly expected to balance the demands of protecting predators from people, and people and their livestock from predators (Treves & Naughton-Treves, 2005; Treves, Wallace, Naughton-Treves & Morales, 2006; Redpath, Bhatia & Young, 2015). Evidence for whether such compromises are cost-effective and sustainable in the long term and whether they are scalable for use in extensive farming is however poor (Madden, 2004; Inskip & Zimmerman, 2009; Treves *et al.*, 2016; Eklund, Lopez-Bao, Tourani, Chapron & Frank, 2017; Van Eeden *et al.*, 2017).

The dearth of appropriate case-control study designs, complex socio-political landscapes and historical idiosyncrasies have together promoted diverse responses to global predation management strategies. In North America, wildlife is publically owned and managed by the state/province with both hunters and public taxes generally providing the money for state-funded management of predation (e.g. population census, setting of hunting quotas) (Geist, Mahoney & Organ, 2001; Heffelfinger, Geis & Wishart, 2013). This approach generates substantial income for local economies, promotes public interest in both consumptive and non-consumptive use of predators and, for the most part, has promoted robust predator populations while keeping livestock losses at apparently acceptable levels (but see Peebles, Wielgus, Maletzke & Swanson, 2013; Teichman, Cristescu & Darimont, 2016). Damage causing predators in the United States (US) are managed under the "Integrated Wildlife Damage Management Program" with appropriate and approved management methods that consider environmental impacts, social acceptability, the legal framework and the costs involved (Bodenchuck, Bergman, Nolte & Marlow, 2013). Importantly, the various wildlife management agencies in the US also engage in applied research relevant to predation management and develop methods of particular relevance for mitigating HPC (Bodenchuck *et al*., 2013).

The Australian model is similar to that of North America, as the government owns and assumes responsibility for predation management and works with states/territories to develop conflict mitigation strategies, undertake research and fund essential management activities (Downward & Bromell, 1990; Allen & Fleming, 2004; Fleming *et al*., 2006; Anon. 2014; Fleming *et al*., 2014; Wilson, Hayward & Wilson, 2017). Individual property owners can use a variety of lethal and non-lethal methods (Fleming *et al*., 2014). Control techniques for damage causing animals include extensive state-managed poison baiting (using 1080 or sodium fluoroacetate) programmes and the 4600 km Dingo Barrier Fence (DBF), that aims to exclude dingoes *Canis dingo* or feral dogs *Canis familiaris* from the entire south-eastern section of the continent (Yelland, 2001). Extensive poison baiting, including the use of aerial drops, is considered acceptable in Australia because many native species have a much higher tolerance to 1080 than introduced species, such as European red foxes *Vulpes vulpes*, feral cats *Felis catus*, European rabbits *Oryctolagus cuniculus* and dingoes or feral dogs (McIlroy, 1986; APVMA, 2008). Additionally, bounties have been used throughout Australia to control "pest" species, and continue to be used in some areas, usually with little to no effectiveness for decreasing livestock predation (Hrdina, 1997; Glen & Short, 2000; Harris, 2016).

Similar to the US and Australia, predation management in Europe initially focused on eradication, with bounties paid for predators killed with unselective trapping, shooting and poisons (Schwartz, Swenson & Miller, 2003). However, unlike the US and Australia, countries in Europe do not have central authorities for managing damage causing animals, which are largely managed on a case-by-case basis. More recently, there have been attempts to establish a framework for the reconciliation of human-predator conflicts, with many European countries affording protected status to large predators in an effort to stimulate their recovery (Zimmerman, Wabakken & Dotterer, 2001; Chapron *et al*., 2014). Members to the European Union also endorsed the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) and the Habitat Directive of the European Union committed to the protection of endangered or endemic species and natural habitats, forcing governments to get actively involved with the management/conservation of various predator species (Andersen, Linnell, Hustad & Brainerd, 2003; Epstein, 2013). Consequently, non-lethal methods such as livestock guarding animals and compensation for livestock losses are now widely used in Europe, and hunting predators is highly regulated and/or prohibited (Cuicci & Boitani, 1998; Stahl, Vandel, Herrenschmidt & Migot, 2001; Treves *et al*., 2017).

By contrast, in many parts of Asia and East Africa (e.g. Kenya), although wildlife is state owned, there is a heavy reliance on tourism to provide revenue for predation management (Kellert, Mehta, Ebbin & Lichtenfeld, 2000; Mburu, 2007). Hunting is often prohibited on the grounds that it is detrimental to wildlife populations and unethical. In addition, with limited incentives for the public to invest in wildlife, many large mammal populations are declining rapidly and levels of conflict around protected areas are high (Ripple *et al*., 2014; 2015). Of concern is that most people living in these regions are subsistence farmers with low income levels and are thus more likely to experience greater impacts from damage causing predators than commercial farmers or urban dwellers (Peterson, Birckhead, Leong, Peterson & Peterson, 2010). In less developed countries, most damage mitigation measures involving predators are community based and lack the resources for coordinated and extensive predator management programmes. In India, where conflicts are chronic and threaten lives and livelihoods, the local authority may permit any person to hunt a "problem animal", if satisfied that the animal (from a specified list) has become dangerous to human life, or is so disabled or diseased that it is beyond recovery.

Context for the South African situation

Unlike the North American, central African and Asian models for predation management, most southern African countries (e.g. Namibia, Zimbabwe and South Africa) have seen the devolution of wildlife rights to private landowners and local communities (Wilson *et al.*, 2017). This places the burden of managing damage causing animals on the individual, but also allows the profits of both consumptive and non-consumptive tourism and wildlife sales to be accrued by the individual. Historically, South Africa is similar to the rest of the world in that it has seen the transitions from a hunter-gatherer system to nomadic pastoralism and ultimately sedentary agriculture, corresponding with a progressive elimination of large predators from much of their historical distribution (Chapter 2). Bounty systems and systematic state-sponsored poisoning of predators provided parallels with the Australian, North American and European systems in the late 1800's (Beinart, 1998; Nattrass & Conradie, 2015).

State-sponsored support for farmers in conflict with predators shifted to extensive fencing in the later 1800s (Beinart, 1998; Nattrass & Conradie, 2015; Chapter 2) and was later combined with state-sponsored hunting clubs to eradicate predators from within fenced areas. For a while, the impacts of predators on livestock appeared to have been ameliorated (Nattrass & Conradie, 2015) and the combination of state-sponsored extensive fencing, poisoning and hunt clubs provided close parallels with the Australian approach to predator control, differing from the US and Europe primarily in the extent of the reliance on fencing. Similar to the US Wildlife Services, the state also funded (limited) predator management research and offered farmer training.

From the mid 1990's, the responsibility of managing predators in South Africa was almost entirely devolved to private landowners, with state-subsidized hunting clubs phased out and dedicated facilities closed down (Du Plessis, 2013). National and provincial authorities now only provide a legal framework within which landowners can protect their stock, offer advice on the range of legal methods for mitigating conflict and managing stock, and manage permitting for research applications from Non-Governmental Organisations (NGO) and tertiary institutions. In the absence of state-funded and coordinated wildlife management outside of protected areas, South African farmers were effectively on their own and increasingly reliant on sectoral organisations (e.g. the Predator Management Forum - PMF), academic institutions and NGOs for advice and advances in understanding and mitigating livestock losses to predators. The livestock farming landscape in South Africa has also changed significantly in recent years, with many small stock producers switching to cattle or game and others ceasing to farm altogether, a trend similar to that observed in Australia (Allen & West, 2013; 2015). Additionally, many livestock farms have converted to so-called "weekend" or absentee farms (Du Plessis, 2013; Nattrass & Conradie, 2015). The result is that in many instances, predation management now occurs in isolation and on relatively small scales (≈ on a single farm or farm consortium) rather than collectively.

In the absence of state-coordinated predation management and research, it is not surprising that management and policy are largely reliant on opportunistic and descriptive research derived from adaptive management outcomes, often at the level of individual farms (Du Plessis, 2013). The lack of appropriate case-control study designs for both lethal and non-lethal predation management is a major impediment to deriving management strategies that can be scientifically and publicly defended (Kerley *et al.*, 2017). As a consequence, there can be intense contestation among increasingly diverse stakeholders as to what works, where and why (Du Plessis, 2013; Nattrass & Conradie, 2015). Some aspects of the debate are political and intertwined with power relations as well as personal value systems (Raik, Wilson & Decker, 2008). With a growing acceptance that ultimately wildlife management is strongly linked to people management (Redpath *et al.*, 2015), there is also increasing awareness of the need to focus more on human behaviour and attitudes; in order to address chronic conflicts and understand the socio-economic factors that influence how society produces food relative to wildlife populations (≈ human dimension of wildlife management – Miller, 2009).

PREDATION MANAGEMENT METHODS

Globally humans have developed an array of techniques to respond to both perceived and real impacts of predation on livestock (Table 6.1, see following page). These techniques consist of lethal and non-lethal methods and are generally implemented as a precautionary (≈ preventative) measure to decrease the risk of livestock predation or as a remedial (≈ reactive) action following predation (PMF, 2016). In South Africa, many livestock producers persist in attempting to reduce predator numbers through unselective, lethal methods (Du Plessis, 2013; McManus, Dickman, Gaynor, Smuts & MacDonald, 2015; Minnie, Gaylard & Kerley, 2016). There are, however, an increasing number of producers who are moving away from an eradication-only approach to non-lethal and more target-specific methods (Minnie, 2009; Van Niekerk, 2010; Du Plessis, 2013; Badenhorst, 2014; Humphries, Hill & Downs, 2015; McManus *et al.*, 2015; Schepers, 2016). Some South African farmers even indicate that they do not actively kill predators, but rather focus on stock and rangeland management to manage livestock predation (Van Niekerk, 2010; Humphries *et al.*, 2015; McManus *et al.*, 2015).

Although communal livestock farmers in South Africa generally make use of animal husbandry practices and disruptive deterrents, a recent survey found that *ca.* 25% of communal livestock farmers surveyed across South Africa indicated they would use lethal methods such as traps and hunting to control depredation if they had the resources to do so (Hawkins & Muller, 2017). This was most pronounced in the low-income area of the Eastern Cape where 95% of livestock owners wished to use lethal methods. In the same study, tolerance to livestock loss was strongly negatively correlated with both the degree of livestock loss and income. The same group remained "extremely angry" after a perceived depredation event and did not find the loss acceptable, despite 40% indicating that they were unsure the loss was due to a predator. Poverty, limited access to resources, unemployment and weak education are common problems on communal rangelands (Bennett, Solomon, Letty & Samuels, 2013). In South Africa, several governmental (e.g. Expanded Public Works Programme) and non-governmental programmes (e.g. Conservation South Africa's Meat Naturally Initiative; Meat Naturally Pty) are aimed at creating wealth and capacity in rural populations.

For the purpose of this chapter, we characterise the range of predation management techniques into seven groups: (1) disruptive deterrents (or primary repellents) which disrupt predator behaviour through a number of mechanisms such as neophobia (fear of novel items), irritation, or pain (Shivik, Treves & Callahan, 2003); (2) animal husbandry practices which include methods that shelter livestock from predation (Shivik, 2006); (3) aversive deterrents (or secondary repellents) which deliver a (negative) stimulus in synchrony with a target species' particular behaviour with such regularity that that the species learns to associate its behaviour with the stimulus (Shivik *et al.*, 2003); (4) provisioning (supplementation) which provides additional food resources to predators in an attempt to deter them from killing livestock (Steyaert *et al.*, 2014); (5) non-lethal population control which aims to suppress or decrease predator population growth or numbers, without killing them (Dickman, 2010); (6) producer management which aims to compensate a livestock owner who has suffered livestock losses as a result of predation (Dickman, 2010); and (7) lethal predator management which aims to eliminate either individual predators or entire predator populations (Dickman, 2010).

Table 6.1. Summary of the available predation management methods and their potential application in the South African context.

Response strategy[a]	Method	Description	Effectiveness[b]	Pros[c]	Cons[c]	Countries practiced/ studied[d]	Application for SA	Available information[e] PR	SC	A
Disruptive deterrents/ Primary Repellents	Normal fladry	Flags or strips of plastic mounted on rope along top of fence	Effective against wolves, but not coyotes, for between 1 to 60 days	Rapid implementation; immediate success	Needs to be extensively installed; animals habituate quickly; not as effective for less territorial species or dominant individuals	North America; South Africa	Could be used for short periods, e.g. lambing seasons (recommended for periods less than 14 days)	Y	Y	Y
	Electrified fladry	Electrified poly-wire, with strips of plastic or flags mounted on the wire	Effective against wolves for up to 90 days	Rapid implementation; immediate success; effective for longer periods compared to normal fladry	Needs power; animals may habituate; high maintenance and installation costs	North America	Could be used for short periods, e.g. lambing seasons (recommended for periods less than 14 days); potential high costs may limit its cost-effectiveness	Y	N	N
	Human herders	People range with livestock and may kraal/boma/corral at night	High with smaller flock sizes and smaller ranges	Improved husbandry and veld management; can make direct observations	Impractical in low density, extensive livestock farming operations, and where labour is expensive; predators may become used to the herdsmen and attack when livestock most vulnerable	East Africa; Europe; US; South Africa	Likely to be effective in most farming areas; high costs may limit its use in widespread farming areas with low densities of livestock; opportunity for job creation (e.g. Jobsfund; EPWP)	Y	Y	Y
	Guarding dogs	Specific dog breeds raised with the flock/herd; defend them against predators	High for most predator species in most circumstances	Long- term provided guard dogs are well trained	Considerable expertise required for training; daily feeding; may attack other wildlife, susceptible to extreme heat and disease/ ticks	Australia; Botswana; Europe; Namibia; South Africa; US	Likely to be effective in most circumstances, given the correct training and care is provided; especially when used in conjunction with well maintained fence system	Y	Y	Y
	Other guarding animals	Donkeys; llamas; camels; alpacas	Efficiency to deter predators may differ depending on the size, alertness and leadership qualities of the individual	No need for extra feeding; easier to bond with livestock	Alpacas & llamas expensive; may harass livestock; may negatively impact breeding behaviour	Australia; Namibia; South Africa; US	Likely to be effective in many circumstances, given the correct individuals are introduced	Y	Y	Y
	Cellular technology	Collar sends a signal when abnormal behaviour is detected	Unknown	Provides remote information on flock/herd status	Needs GSM coverage; there are response time limitations and false alarms; ineffective in extensive areas where farmers are not able to reach their stock quickly	South Africa	Can work in most farming areas, but its feasibility may be limited by its inability to transfer a signal in extensive areas where stock cannot be reached quickly	Y	Y	Y

[a] see "Predation management methods" for a description; [b] effectiveness of the method to decrease predation losses – see "Predation management methods" for detail; [c] including the methods practicality to implement, implementation and maintenance costs and potential environmental impacts; [d] examples based on the literature included in "Predation management methods"; [e] type of publications available and consulted to assess each method, PR = scientific, peer reviewed publications, SC = semi-scientific publications, A = anecdotal – see Box 6.4

	Disruptive stimuli	Flickering lights and acoustic cues associated with human activity	Effective against a variety of species for short periods	Initial success; generally easy to set up and use; can be effective in targeted species specific application	Rapid habituation; devices can be expensive to buy and running costs high; difficult to scale up on large properties	Australia; Kenya; South Africa; US	Can be used as an addition to other techniques for short periods; may not work for all predator species; more successful in small areas; currently not recommended for more than two weeks at a time	Y	Y	Y
	Protection collars	Physical protection against neck bites (including bell and poison collars)	Only effective for throat bites and only for limited periods	Easy to use and apply; targets damage causing predators only; no impact on other wildlife (except where poison collars are used and poison gets ingested by non-target wildlife)	Predators get habituated to protection collars and attack the hindquarters; expensive to apply to all stock; intensive management; needs regular adjustment	Norway; South Africa; US	Can be used in addition to other techniques for shorter periods; may not work against all predator species; not recommended for more than two weeks	Y	Y	Y
Husbandry practices	Predator proof fencing	Physical separation of predators and livestock by utilizing a fence designed to keep predators out	Generally effective at excluding most canids; less effective at excluding species that are able to climb & jump over fences (the latter require specific designs)	Solid barrier; cost effective in the long term	Expensive to install and maintain; digging animals may be persecuted; limits movement of non-target species; may have negative ecological effects on the ecosystem	Australia; South Africa; US	Communal rangelands and large scale farms; certain adaptations can be made in fences to exclude damage-causing predators but allow certain other species to pass through	Y	Y	Y
	Night enclosures	Mobile kraals or permanent enclosures to protect livestock at night	Highly effective at limiting predation from a variety of carnivore species	Inexpensive to set up	Intensive management; fixed kraal site increase risk of erosion, trampling and overgrazing; increased risk of disease; high parasite load; rapid spreading of disease	Botswana; Kenya South Africa; Zimbabwe	Likely to be effective on most farms, but it may be less practical and more expensive to implement in extensive farming areas	Y	Y	Y
	Seasonal enclosures	Lambing occurs in sheds or "lambing camps", i.e. smaller camps close to homestead during lambing season	Highly effective to protect young, vulnerable stock	Protect stock against predation during their most vulnerable period (i.e. lambing period)	Expensive; intensive management (especially on large scale farms)	South Africa; US	Most applicable on small stock farms, although its cost-effectiveness may limit its use	Y	Y	Y
	Rotational/Selective grazing	Smaller camp system, keeping ewes & lambs closer to homestead; keeping livestock away from high risk areas	Potentially moderate to high	Inexpensive	Intensive management & labour; moving stock continually may increase stress levels	South Africa; US; Zimbabwe	Likely to be effective on most farms; may be less practical and more expensive to implement in extensive farming areas	Y	Y	Y
	Timing of breeding	Ensuring livestock lambing/calving asynchronous with predator breeding; predation often peaks during the lambing or calving seasons	Potentially effective in decreasing predation on lambs/calves	Higher lambing/calving success, reduces the risk of predation on young stock; low cost manipulation	Need to be monitored; very intensive; not effective for predators that breed aseasonally; biological and grazing limitations	South Africa; US	Small to medium sized farms, although its feasibility could be limited by various factors	Y	Y	Y

Table 6.1. continued...

Response strategy[a]	Method	Description	Effectiveness[b]	Pros[c]	Cons[c]	Countries practiced/ studied[d]	Application for SA	Available information[e] PR	SC	A
Husbandry practices cont...	Livestock breed selection	Some livestock breeds are less vulnerable to predation	Unknown	Long term solution if breed has effective predator defence	Less viable under conditions that better suit only certain species; the market price of certain breeds could make them economically less viable; predators may learn to overcome defences	South Africa	Small to medium sized farms	Y	Y	Y
	Altering herd composition (≈ flerds)	Mixed herds (e.g. sheep and cattle) provides protection for smaller livestock	Effectively reduced coyote predation on sheep but not goats in the US	Cattle act as guards for sheep if they have bonded; low cost and diversifies produce	If cattle and small sheep don't bond, there is no advantage; veld may not suit livestock types or different grazing needs	US	Small stock farms, although it would be limited by livestock breed and grazing availability	Y	N	Y
	Sanitation	Regular carcass removal & destruction	Effective to reduce the severity of predation, presumably because the densities of predators decrease because food availability decreases	Simple to implement; reduces total food available to predators and scavengers; prevents further habituation to "unnatural" prey (e.g. "introducing" livestock as prey)	Labour intensive and difficult to locate carcasses on large farms	US	Most practical to implement on small to medium size farms; may be limited in situations where the damage-causing species is not usually a scavenger	Y	N	N
Aversive Deterrents/ Secondary Repellents	Conditioned Taste Aversion (CTA)	Animals learn to associate food with illness and subsequently avoid it	Generally ineffective; predators develop an aversion against the baits but continue to kill livestock; predators able to recognise the taste of the emetic	Could potentially repel target individuals	Predators smell and taste chemical and avoid eating; many aversive chemicals are carcinogenic; time consuming; expensive; difficult to catch all non-territorial animals; impractical to implement	UK; US	All farms, although it is unlikely to be effective and practical in South Africa	Y	N	Y
	Bio-fences	Strategic placement of scent marks or sounds that imitate the presence of conspecifics or other competitors in an area	Deterred African wild dogs and wolves but not coyotes; unknown if it decreases livestock predation	Easily applied; non-lethal; inexpensive	May require multiple applications in one year; short term effectiveness	South Africa; US	Could be effective for highly territorial species, although the method still need extensive testing	Y	Y	N

[a] see "Predation management methods" for a description; [b] effectiveness of the method to decrease predation losses – see "Predation management methods" for detail; [c] including the methods practicality to implement, implementation and maintenance costs and potential environmental impacts; [d] examples based on the literature included in "Predation management methods"; [e] type of publications available and consulted to assess each method, PR = scientific, peer reviewed publications, SC = semi-scientific publications, A = anecdotal – see Box 6.4

	Shock collars	A collar with two prongs which administer a shock when animal approaches a designated area/target	Effective for coyotes under experimental conditions in US	Very targeted	Expensive and impractical to implement and maintain for widespread and abundant predators; limited by battery life animals will constantly test boundaries	US	All farms; although it is unlikely to prove a practical and cost-effective method under South African conditions; could be useful for endangered or threatened predator species	Y	Y	Y
	Electric fencing	Any stock proof fencing with electrified wires, which administers a non-lethal shock; or electrification of an existing predator proof fence	Increased effectiveness compared to normal fencing, because predators avoid the risk of being shocked	Long term effectiveness to exclude predators; solid barrier; long-term cost-effectiveness	Expensive to install and maintain; limits movement of non-target species; lethal for select wildlife (e.g. tortoises)	Australia; Japan; South Africa; US	All farms, although its costs and maintenance may affect its feasibility in larger areas; more suited to small to medium sized farms	Y	Y	Y
Provisioning	Supplemental feeding	Provisioning predators with alternative food to livestock	Potentially high	Initially quite effective	Might increase condition and hence fecundity of predators; may collapse territorial behaviour and increase predator densities	Europe; North America; South Africa	Can be used in addition to other techniques; certain predators may only take unnatural food (i.e. dog pellets) for short periods	Y	N	Y
Non-lethal population control	Translocation	Predator is removed from area where livestock losses occur	Method is generally only effective when the predator can be relocated to an area with a relatively low density of conspecifics and where livestock is absent	Immediate reprieve if damage-causing animal is removed	Expensive; vacant territory quickly filled; for social species the entire group needs to be removed; could be difficult to find a suitable release site	Botswana; Canada; Namibia; South Africa	Likely to only be feasible for protected species that occur at low densities; only where a suitable release site can be located	Y	Y	N
	Fertility control	The reproductive potential of an animal is eliminated or reduced through surgery or injection	Successfully reduced coyote predation on small stock in the US	Slow population growth; territorial animal(s) not removed	Time consuming; costly because all individuals in an area must be targeted; would require the capturing and sterilization of or the application of contraceptives to all adults of a specific sex within a population	South Africa; US	All farms, although it is unlikely to prove a practical and cost-effective method under South African conditions	Y	N	Y
Producer management	Compensation schemes	Paying farmers for livestock losses	If well administered and measures are in place to monitor and confirm claims of predation, the method may limit persecution of damage-causing carnivore species	Reduction in retaliatory killing and more tolerance to predators; when designed and implemented correctly it may encourage better livestock management practices	Potentially expensive; open to fraudulent claims; may disincentivise good husbandry in some instances; difficult to monitor over extensive areas; only shifts the economic costs of livestock predation	Asia; Europe; Kenya; Pakistan; US	Communal rangelands and large scale farms; although it is unlikely to be a financially feasible and practical option where livestock predation is high	Y	N	N
	Insurance programmes	Livestock are insured against losses	Can be implemented successfully where livestock flocks/herds are small and livestock predation is low	Increases predator tolerance and encourages farmers to mitigate against livestock predation	Potentially costly and open to fraudulent claims; difficult to monitor over extensive areas	Botswana; India	Communal rangelands and large scale farm, although it is unlikely to be a financially feasible and practical option where livestock predation is high	Y	N	Y

Table 6.1. continued...

Response strategy[a]	Method	Description	Effectiveness[b]	Pros[c]	Cons[c]	Countries practiced/ studied[d]	Application for SA	Available information[e] PR	SC	A
Producer management cont...	Financial incentives	Farmers are provided with incentives and business opportunities for mitigating HPC and reducing poaching; bounties are paid to kill certain species	Financial incentives motivate producers to implement or commit to certain predation management methods or to hunt certain species or to tolerate certain species	Reduction in retaliatory killing; reduction in blanket lethal control; increases predator tolerance (except when bounties are paid)	Potentially costly and open to fraudulent claims; difficult to monitor over extensive areas; only shifts the economic costs of livestock predation	Australia; Mongolia; North America; South Africa	Subsidies/Tax rebates is likely to be an effective way to motivate farmers to implement certain methods; due to a limited market for "wildlife friendly brands", it is unlikely to be economically sustainable on a large scale	Y	Y	N
Lethal predator management	Shooting	High powered rifle used on target species, in combination with calling or from an aircraft	Moderate to high in the short term	Species specific; cheap; easy to implement on the individual farm level	Creates vacancies for other predators to disperse into; has to be implemented annually; generally unselective towards the damage-causing individual; older individuals may learn to avoid shooting; counterproductive and increases predator numbers	Australia; North America; Norway, South Africa	Excessive shooting may be counterproductive due to the impact of immigration and "compensatory breeding"; where 'shooting' is applied, measures should be put in place to ensure that only the damage-causing individuals are targeted	Y	Y	Y
	Denning	Removal and or killing of young at dens	Effectively reduced coyote predation on sheep in the US	Easy to implement if den locations on a property are known	Expensive; time consuming, annual application needed; involves indiscriminate killing; possibility to activate "compensatory breeding"	South Africa; US	The method's potential ecological effects and unethical nature may limit its usefulness in South Africa	Y	Y	Y
	Hunting dogs	Detecting, chasing, luring and killing predators with the aid of trained domestic dogs	Historical data suggest that this method was not very effective in South Africa	Can be trained to be reasonably selective	Expensive, generally non-selective, successfulness influenced by a variety of factors including seasonality, climatic conditions and topography	Botswana; Costa Rica; Kenya; North America; Phillipines; Russia; Siberia; South Africa; UK	May have limited application to chase or point potential damage-causing predators; correct training may increase the method's successfulness	Y	Y	Y
	Poisoned baits	Meat or manufactured baits laced with poison	Poisoned baiting has been shown to be successful at decreasing the populations of some predators; although there are some cases in Australia where livestock predation continued after the application of poisoned baits	Cheap; easily applied	Indiscriminate; short term success; some predators may avoid poisoned baits (bait aversion can occur)	Australia; South Africa; US	Illegal in most countries; not recommended because of its indiscriminate nature in the South African context	Y	Y	Y

[a] see "Predation management methods" for a description; [b] effectiveness of the method to decrease predation losses – see "Predation management methods" for detail; [c] including the methods practicality to implement, implementation and maintenance costs and potential environmental impacts; [d] examples based on the literature included in "Predation management methods"; [e] type of publications available and consulted to assess each method, PR = scientific, peer reviewed publications, SC = semi-scientific publications, A = anecdotal – see Box 6.4

Lethal predator management cont...	Coyote getters/M44	Poison from a cartridge discharged into face and mouth of predator when the device are triggered	Effective to capture black-backed jackal in South Africa; unknown to what extent it decreases livestock predation	More selective than baited poisoning; poison is more secured compared to baited poisoning	Traditional forms of getters are indiscriminate; capture bias towards younger animals; some species learn to avoid devices	Australia; South Africa; US	Traditional forms of "getters" are not recommended because of its indiscriminate nature	Y	Y	Y
	Poisoned collars	Collars with pouches that contain a lethal dose of poison	Potentially high, but is extremely context specific	Most selective application of poison; selective towards predators that bite livestock in the throat area where the poison pouches are situated	Spillage can potentially kill livestock; possible negative environmental impact when scavengers feed on poisoned carcasses (dependant on the poison that is used); predators may get habituated to the collars; cost-prohibitive for extensive grazing systems	South Africa; US	Can effectively be used to target damage-causing individuals of certain species; important to use it only where and when damage has been caused; can be fitted to 10 - 20 individuals and move rest of stock to another camp; recommended for not more than seven days	Y	Y	Y
	Cage traps	Baited cages for live trapping of predators	High efficacy to capture certain species; typically little success with canids	Can be effective on felines and primates; non-target species are released; easy to implement	Not always possible to know whether the specific damage-causing individual has been caught; traps need to be monitored daily	Namibia; North America; South Africa	Effective to capture certain species	Y	Y	Y
	Leghold devices	Traps the foot of the predator	Effective to capture certain damage-causing species; but unknown to what extent it decreases livestock predation	With careful placement and setting it can be more selective and reduce injuries; modified traps (≈ soft traps) may cause fewer injuries; low cost	Labour intensive if traps are checked frequently; potentially unselective if poorly set; the traditional "gin" trap can cause severe injuries and is now illegal	Australia; North America; South Africa	Traditional forms of traps are not recommended because of their indiscriminate nature and because of the injuries they can cause to some species	Y	Y	Y
	Foot loop traps	Traps the foot of the predator	Typically little success for capturing canids in Northern America; unknown to what extent it decreases livestock predation	With careful placement and setting it can be more selective and reduce injuries; low cost; easy to implement	Labour intensive if traps are checked frequently; potentially unselective if poorly set; can cause severe injuries if poorly set and not checked	North America; South Africa	Traditional "snares" are not recommended because of their indiscriminate nature; but may be effective for certain species, especially felids	Y	Y	N
	Neck or body snares	Traps the predator around the neck or body	Neck snares are viewed as one of the most effective methods to capture canids in the US; unknown to what extent it decreases livestock predation	With careful placement and setting it can be more selective and reduce injuries; low cost; easy to implement	Labour intensive if traps are checked frequently; unselective; can cause severe injuries if poorly set and not checked	US	Not recommended without the use of a "stopper"; also indiscriminate if poorly set; not recommended for felids	Y	Y	N
	Killer trap	Placed at an opening under a fence; traps on the head or body of the predator	Unknown	Cheap; easily applied	Indiscriminate	South Africa	Not recommended because of its indiscriminate nature	N	N	Y

Disruptive deterrents

Fladry

Fladry consists of brightly-coloured pieces of cloth tied at specific intervals along a line, and was originally used to direct the movements of wolves *Canis lupus* (Okarma & Jędrzejewski, 1997). This non-lethal method is easy to implement and, apart from its installation, may require minimal logistics (Young, Miller & Essex, 2015). It has been shown to successfully deter captive wolves and coyotes *Canis latrans* for short periods (≈ *ca.* 1 day) from areas where food is placed (Musiani & Visalberghi, 2001; Mettler & Shivik, 2007). Under field conditions, it was found to successfully deter wolves from various livestock farms in the US (Musiani *et al.*, 2003; Davidson-Nelson & Geihring, 2010), but not coyotes (Davidson-Nelson & Geihring, 2010). Musiani *et al.* (2003) found that the usefulness of fladry may, however, be restricted to a finite period (1-60 days). Furthermore, Mettler & Shivik (2007) found that fladry was less successful against dominant predator individuals that generally take more risks when it comes to livestock predation.

Electrified fladry differs from normal fladry in that the fladry line consists of an electrified poly-wire. It is more difficult to install than normal fladry and it is also more expensive (Lance, 2009). It may, however, be more successful at deterring predators than normal fladry. For example, Lance, Breck, Sime, Callahan & Shivik (2010) found that under test conditions, electric fladry deterred wolves for longer (≈ 2 to 10 times) compared to normal fladry. In addition, Gehring *et al.* (2006) found that electrified fladry deterred wolves from livestock farms in Michigan, US for up to 90 days.

To date, fladry has not been tested in South Africa, but various farmers do apply the concept (e.g. hanging brightly coloured containers or flags on fence lines – N. Viljoen, 2017, pers. comm.). Although fladry might successfully deter certain predators in South Africa, it is likely that the method will only be effective in the short term because of habituation by the target species. Electrified fladry may have a longer lasting effect, presumably because of its aversive properties. Overall, the cost-effectiveness of and the practicality of implementing fladry may be limiting factors for its successful implementation, especially on extensive livestock farms.

Human herders

With the exception of isolated cases where a predator is killed by a herder, human herders are considered a non-lethal predation management technique. While a trend away from human herders started to occur over 100 years ago in Australia (B. Allen, 2017, pers. comm.) and after the mid-1990's in the US (Hygnstrom, Timm & Larson, 1994), the method is still widely used in Africa and Europe (Kaczensky, 1999; Ogada, Woodroffe, Oguge & Frank, 2003; Patterson, Kasiki, Selempo & Kays, 2004). In the latter settings, livestock herds/flocks are generally kept in relatively small areas and are enclosed at night. McAdoo & Glimp (2000) hypothesised that herders will likely be a successful predation management method in most cases because they can provide a reliable deterrent. Herders are in a good position to make field observations on the condition of fences, presence of predators and the condition of the veld which can be of value for any adaptive management used by the farmer (Palmer, Conover & Frey, 2010; Hawkins, 2012) and employing herders may provide for job creation through new or existing government supported initiatives (e.g. Jobsfund; Extended Public Works Program). However, certain predators may become habituated to the presence of a herder and adapt their activity to attack stock when they are most vulnerable (Du Plessis, 2013; Fehlmann, O'Riain, Kerr-Smith & King, 2017). Herders may also be less effective when flock or herd size increases, when flocks or herds are widely dispersed, and as grazing area (≈ farm or camp size) increases (Shivik, 2004). The latter issues could be less problematic when herders also use working dogs to help guard their stock.

In South Africa, herders are successfully used by most subsistence farmers (Webb & Mamabolo, 2004; Constant, Bell & Hill, 2015; Hawkins & Muller, 2017); presumably most of these farmers now also graze their stock in relatively small areas. While some commercial small stock farmers in South Africa employ herders to guard their stock (Van Niekerk, 2010), and anecdotal reports point towards them being effective (Viljoen, 2015), there is no published scientific evidence available to confirm the effectiveness of the method. In addition, it is speculated that herders may not be cost-effective in the commercial context in South Africa because of labour costs (Viljoen, 2015). This, and the extensive nature of many commercial livestock farms in South Africa, will likely make herders a less viable option. More recently, modern shepherds (with and without guard dogs) were trialled in Namaqualand using a Before-After-Control-Impact design and the results of this study will be important for assessing the prospects of this method on small livestock farms in South Africa (C. Teichman, 2017, unpublished data).

Guarding animals

A variety of animals have been used around the world to guard cattle, sheep, and goats from predators. The best-known of these are: dogs *Canis lupus familiaris*, donkeys *Equus asinus*, llamas *Lama glama*, and alpacas *Vicugna pacos* (Hygnstrom *et al.*, 1994; Rigg, 2001; Jenkins, 2003; Weise, Vidu & Fernandez-Armesto, in Press). Although it is the larger dog breeds that have traditionally been developed as guarding animals (Andelt, 1992; Landry, 1999), there are instances where other smaller, mixed breed dogs have also been successfully used in this role (e.g. Coppinger & Coppinger, 2001; Gonzales *et al.*, 2012; Horgan, 2015). The most commonly used, and hence most well-studied, guarding animal is the livestock guarding dog (LGD) (Rigg, 2001; Gehring, VerCauteren & Landry, 2010; van Bommel & Johnson, 2012; Allen, Stewart-Moore, Byrne & Allen, 2016). A variety of specifically bred LGDs are available (Rigg, 2001), although some local, mixed breeds are also employed in some areas (Figure 6.1).

Figure 6.1. Examples of livestock guarding dogs. Anatolian Shepherd or Kangal dog (left) and mixed-breed livestock guarding dogs used in Namibia (right). Photos: Gail Potgieter.

In Namibia and Botswana, LGDs have been used successfully against most of the common predators that occur on farmlands in these countries, including black-backed jackals *Canis mesomelas*, caracals *Caracal caracal*, cheetahs *Acinonyx jubatus*, leopards *Panthera pardus* and chacma baboons *Papio ursinus* (Marker, Dickman & MacDonald, 2005; Horgan, 2015; Potgieter, Kerley & Marker, 2016). In Botswana, relatively small, mixed-breed dogs are effective at reducing livestock losses, probably by disrupting predators from the normal hunting sequence through barking (Horgan, 2015). Similarly, large purebred dogs in Namibia appear to non-lethally prevent cheetah and leopard predation, and are known to confront and kill black-backed jackals and caracals (Potgieter *et al.*, 2016).

LGDs in Namibia and Botswana are usually used to guard small stock that are kraaled (≈ corralled) at night, and human herders are frequently employed to keep the livestock together (Potgieter, Marker, Avenant & Kerley, 2013; Horgan, 2015). In the absence of herders, the sheep or goats generally stay together as a flock, although some farmers report that their guarding dogs also help keep the flock together (Horgan, 2015). In Australia, some farmers use LGDs on large properties (> 10,000 ha) under an extensive management system where the livestock are not herded and the dogs are allowed to roam freely throughout the property (van Bommel & Johnson, 2012). Under these circumstances, it appears that LGDs are most effective when guarding 100 or fewer head of livestock per dog (van Bommel & Johnson, 2012). One guarding dog puppy should be introduced to the livestock at a time, as puppies introduced at the same time tend to increase problems of playing roughly with the livestock. However, once an adult dog has been established with the livestock, introducing a new puppy can be easier as the older dog trains the younger one (van Bommel, 2010). In this way, a large group of LGDs can be used to protect extensively managed livestock over a large area (van Bommel & Johnson, 2012). This is achieved through direct LGD protection or guarding of sheep, not through indirect exclusion of predators from areas where sheep are grazed (Allen *et al.*, 2016).

Hansen & Bakken (1999), Gingold, Yom-Tov, Kronfeld-Schor & Geffen (2009) and Potgieter *et al.* (2016) found that LGDs may have a negative impact on the environment by chasing wild ungulate species or by killing intruding wildlife that pose no threat to or competition with livestock for grazing. Unless there are vulnerable or protected species in the area where LGDs are employed, the advantages associated with this method will likely outweigh the potential negative impacts. Timm & Schmidtz (1989) also reported cases where LGDs killed livestock. The latter behaviour is more likely where more than one LGD is used to protect a flock or herd, and is related to play behaviour rather than aggression (Snow, 2008). It is, however, possible to limit livestock and wildlife killing behaviour in most LGDs with suitable training and care (Dawydiak & Sims, 2004; Potgieter *et al.*, 2016).

The use of LGDs is considered an ethically acceptable predation management method in South Africa (Smuts, 2008) and there is evidence confirming that LGDs can be effective under South African farming conditions. In a study by Leijenaar, Cilliers & Whitehouse-Tedd (2015), where LGDs were placed on 135 livestock farms throughout the North West and Limpopo provinces, farmers reported significant decreases in livestock predation across various farm types, including small stock, cattle and game farms after LGDs were introduced. In addition, an unpublished study by Herselman (2006) demonstrated that LGDs successfully reduced predation on 43 small stock farms across South Africa. McManus *et al.* (2015) also found that LGDs may be relatively cost-effective, compared to lethal alternatives (in this instance shooting, foothold traps and coyote-getters). It is widely accepted that the success of any LGD programme is intimately linked to the selection of a breed and individual dog for a particular area and livestock, the quality of the training before deployment, and their care/husbandry while they are in the field (Dawydiak & Sims, 2004; van Bommel, 2010).

When utilised correctly, alpacas, donkeys, and llamas may deter a variety of smaller carnivores in different settings (Jenkins, 2003). Advantages of alternative guarding animals compared to LGDs include reduced bonding time with livestock (4-6 weeks, compared to about 6 months for LGDs) (Jenkins, 2003) and less care. Donkeys, alpacas and llamas have been used in the US and Australia with flocks and herds of between 200-300 head of small stock, on small or medium-sized properties (between 100-400 ha) (Walton & Field, 1989; Andelt, 1992; Jenkins, 2003). Farmers in North America and Australia report that donkeys, llamas and alpacas are less effective when the livestock spread out over large properties with an undulating landscape (Jenkins, 2003). In Australia, they are also mostly effective against foxes, but not dingoes (B. Allen, 2017, pers. comm.). However, donkeys used in Namibia effectively reduced livestock losses on extensive farms (5 000 to 8 000 ha) with cattle herds of 70-80 head, under which circumstances they may also keep the cattle together in one herd (Weise *et al.*, in Press).

Groups of donkeys or llamas tend to stay closer to their conspecifics than with the livestock they are meant to guard (Jenkins, 2003; Weise *et al.*, in Press). However, introducing a female donkey (jenny) and her foal to livestock can be highly effective, as jenny's are especially protective of their young (Bourne, 1994; Jenkins, 2003). The main behavioural problems associated with these alternative guardian animals are: aggression towards new-borns, mounting ewes in the flock and aggression towards people (Jenkins, 2003; Weise *et al.*, in Press). These issues can be resolved or minimised by separating the guarding animal from the flock during lambing season (although this may be counterproductive as this is often when predation risks are the highest), not using intact males as guardians, and maintaining regular human contact with the guarding animal (Weise *et al.*, in Press).

Like LGDs, alternative guarding animals have been proposed as an ethically acceptable predation management method for South African farmers (Smuts, 2008). There is, however, very limited scientific information on alternative guarding animals in South Africa. There is an unconfirmed report of alpacas deterring chacma baboons from attacking stock (Lindhorst, 2000). In addition, according to Schepers (2016), South African game farmers list alternative guarding animals as one of the predation management methods that many prefer to use, this indicates that alternative guarding animals are at least perceived to be successful. McManus *et al*. (2015) tested the use of alpacas on one farm as part of a larger study on non-lethal predation management methods, and it appears that this was successful, although the authors did not present the results for alpacas separately to the other methods they tested, and there was no replication of the study. Similar to LGDs, it is important to follow correct procedures wherein alternative guarding animals are utilised to ensure best results (e.g. Jenkins, 2003; Weise *et al*., in Press).

Cellular communications technology

Cellular communications technology can be incorporated into an animal collar which sends a radio signal to the farmer when abnormal behaviour (e.g. running) is detected within a livestock herd (Lotter, 2006; Viljoen, 2015; PMF, 2016) or when a collared predator cross a predetermined boundary (also see Box 6.1). The farmer can then investigate and respond accordingly. A disadvantage of cellular communications technology, however, is that it is limited by cellular reception nodes in many of the farming areas in South Africa. The use of satellite transmission technology could overcome the issue of poor reception, but the relatively high cost of satellite collars will likely prohibit their use. Cellular communications technology may also be less practical to use on extensive farming operations where it is not possible to reach the livestock quickly. Also, the false alarms attributed to livestock running for reasons other than predators may reduce farmer response rates to actual predation events. This can be mitigated to an extent by linking areas where animals are running to other elements like water and food sources for livestock and fence lines.

Disruptive stimuli

Disruptive stimuli can be applied through devices (≈ fear inducing or frightening devices) that generate noises, lights, reflections or smells (Pfeifer & Goos, 1982; Bomford & O'Brien, 1990; Hygnstrom *et al*., 1994; Shivik & Martin, 2000; Shivik *et al*., 2003; VerCauteren, Lavelle & Moyles, 2003; Figure 6.2). Bell collars are primarily applied as a disruptive stimulus, although they may also act as a protection collar (see "Protection collars"). Breck, Williamson, Niemeyer & Shivik (2002) and Darrow & Shivik (2009) noted that lights and noises were effective at deterring coyotes and wolves under test conditions in the US. In addition, Linhart, Dasch, Johnson, Roberts & Packham (1992) recorded a decrease of *ca*. 60% in sheep losses to coyotes when a disruptive device that produced a combination of lights and noises was used on livestock farms in Colorado and Wyoming, US. Similarly, VerCauteren *et al*. (2003) recorded no coyote damage over a period of two months on a sheep farm in Wyoming, US after an acoustic device was employed.

Figure 6.2. Solar powered acoustic and light generating device (≈ frightening device) set on a livestock farm in South Africa. Photo: Niel Viljoen.

Despite these apparent successes, the effectiveness of the various disruptive devices are short-lived because carnivores habituate rapidly to them (Smith, Linnell, Odden & Swenson, 2000; Shivik *et al*., 2003). Various studies that tested the use of different disruptive devices to deter primates found that effectiveness is limited to a finite period because primates are easily habituated (Sitati & Walpole, 2006; Kaplan, 2013; Kaplan & O'Riain, 2015). Rotating deterrent strategies (multiple stimuli used in various combinations at irregular intervals – Koehler, Marsh & Salmon, 1990) or developing deterrents according to the target species' biology, i.e. using a predator model or playing back target species' distress calls (Belant, Seamans & Tyson, 1998), are two ways to delay habituation. However, most frightening devices are only effective in relatively small areas over relatively small timeframes, and the implementation and running costs can be high (Gilsdorf, Hygnstrom & VerCauteren, 2002).

Despite the use of a variety of disruptive devices by many South African livestock farmers (Van Niekerk, 2010; Badenhorst, 2014; Schepers, 2016), their effectiveness to manage livestock predation has not been tested scientifically. However, an emerging concept which integrates a combination of disruptive stimuli to form a virtual fence against predators could prove to be effective in the long term (see Box 6.1).

Box 6.1 Baboon management and virtual fencing

Baboons are not traditionally considered to be serious predators of livestock. However, in communal lands in Zimbabwe, a household survey by Butler (2000) reported that baboons were responsible for more losses than larger predators like lions and leopards (mainly young goats targeted by adult male baboons), although economic costs were still largely determined by lion predation which targeted more valuable livestock. It has also become increasingly evident in recent years that, on a local scale, baboons could become additional predators of small stock in areas like the Karoo, especially during droughts (Tafani & O'Riain, 2017; Chapter 9). While no mitigation measures exist to reduce baboon predatory behaviour *per se*, various management strategies for mitigating baboon raiding behaviour have been proposed and tested in both rural and urban environments throughout Africa (Naughton-Treves, Treves, Chapman & Wrangham, 1998; Hill & Wallace, 2012; McGuinness & Taylor, 2014; Richardson, 2016) and Saudi Arabia (Biquand, Boug, Biquant-Guyot & Gauthier, 1994). Management strategies are generally tailored to local problems and seldom achieve long-term success because baboons readily habituate to deterrents and overcome physical barriers (Kaplan & O'Riain, 2015; Howlett & Hill, 2016; Fehlmann *et al.* 2017).

Recently, however, successes have been achieved in baboon management in and around the urban areas of Cape Town (Richardson, 2016; Fehlmann *et al.*, 2017; Richardson *et al.*, 2017). Over the past five years, teams of rangers, using aversive tools like paintball markers and bearbangers (≈ .22-calibre blank powered flare gun that fires cartridges that travel 20 m then explode with a bang), have kept baboons out of the urban areas of Cape Town for over 98.5% of the time (Richardson *et al.*, 2017). Baboons are able to learn raiding (Strum, 2010; Richardson *et al.*, 2017) and predatory (Strum, 1981) behaviours from other troop members, so sometimes lethal management (with strict protocol conditions – CapeNature, 2011) is required to break this training cycle. A similar combination of non-lethal deterrents with selective removal of problem individuals could be tested on South African farms where baboons are killing livestock, if the offending individuals can be identified. However, a promising new and less labour intensive non-lethal strategy that can be tested in a livestock farming context, is virtual fencing (Richardson *et al.*, 2017).

A virtual fence can be defined as a non-physical structure serving as a barrier or boundary (Umstatter, 2011). It can therefore be likened to a territorial boundary which may be advertised in a variety of ways including loud calls, scent marks and visual cues (Hediger, 1949; Mech, 1970; Richardson, 1993). These advertisements are designed to keep intruders away through fear of retribution (physical punishment or death), if caught (Hediger, 1949; Richardson, 1993). In both instances, the mechanism by which the boundary is maintained, is embedded in the "landscape of fear" theory (Laundre, Hernandez & Ripple, 2010). Studies of prey responses to different predation risks have shown that most individuals realize those risks and adjust their behaviour to reduce them, even at the cost of losing feeding opportunities (Caro, 2005; Landré *et al.*, 2010, Cromsight *et al.*, 2013). Furthermore, behavioural responses should vary depending on how the level of risk varies in time and space (Cromsight *et al.*, 2013). If the virtual fence boundary is well defined, i.e. spatially predictable, an animal will know it is approaching the boundary (as it would a territorial boundary) and therefore be wary. However, if the signal is temporally unpredictable, the animal will not know when the retribution is likely to happen. This will create a high level of uncertainty which will compound the level of stress (and fear) (Cromsight *et al.*, 2013; Richardson *et al.*, 2017). Although the timing of the activation of the virtual fence must be unpredictable, its activation must remain a certainty. An intruder should never be allowed to intrude without being punished (Richardson, 1993). Similarly, although location of the fence line should be predictable, the position of the "attack" along the fence line should remain unpredictable, thus further enhancing the fear factor.

Species that have close-knit social structures are ideal for virtual fence designs, because a single GPS-collar on a high-ranking individual represents the larger family group's movement. Virtual fences are therefore best suited to slowly reproducing, long-lived and group-living species with overlapping generations (Jachowski, Slotow & Millspaugh, 2014). Baboons are therefore ideally suited to management by virtual fencing. In view of this, a 2 km virtual fence (between the Steenbras Dam and the Indian Ocean) was designed to keep baboons in the Steenbras Nature Reserve and prevent them from raiding Gordon's Bay in the Western Cape Province (Richardson *et al.*, 2017). A landscape of fear was generated by playing the calls of natural predators, alarm calls, the sounds of prey being killed, or predators fighting over their kills. In addition, loud scary bangs or whistles were produced by means of "bearbanger" pyrotechnics. The high variety of stimuli was designed to add to the unpredictability of the system, and therefore to reduce the chances of habituation (Flower, Gribble & Ridley, 2014).

All these stimuli were produced by remotely activated action stations, each of which contained two high ampere speakers and a double-barrelled bearbanger (Richardson *et al.*, 2017). The troop's position was determined on a daily basis via GPS radio telemetry. When the troop was more than a day's foraging distance from the virtual fence it could be ignored for the rest of the day. However, if the troop was closer, it was monitored remotely throughout the day. In total, three baboons were radio collared, and they transmitted readings once every 10 or 30 minutes. If the troop approached to within 500 m of the virtual fence, then a team of rangers was sent out to observe from a distance, and unobtrusively deploy the action stations (Figure 6.3) if the baboons were continuing to approach. Five action stations were placed about 75 m apart and out of sight, but directly in the path of the baboons. If the troop advanced to within 50 – 70 m of the virtual fence, a selection of deterrent calls was played before firing off 1 – 3 bearbangers. All activations of the virtual fence were successful in repelling the baboons. During the first eight months of implementation, the virtual fence needed to be activated 13 times, but only three times in the following eight months (Figure 6.4; last activation in April 2017). This suggests that the virtual fence had created an effective landscape of fear (Richardson *et al.*, 2017). After being first activated in January 2016, the baboon troop tried to cross the fence another 15 times but was effectively repelled each time. The virtual fence was therefore 100% effective in keeping the troop out of Gordon's Bay

(Richardson *et al.*, 2017). At this stage, there is no evidence to suggest that the baboons are becoming habituated to the virtual fence. This is ascribed to the scariness and variety of the stimuli produced.

Figure 6.3. **Virtual fence, Mark I-model, remote controlled action station. Note the two double-barrelled bearbanger guns, loaded with banger (red) and whistler (green) flares, and one high ampere speaker. The Mark III-model action stations are fully waterproof and have two speakers and only one gun. Photo: Phillip Richardson.**

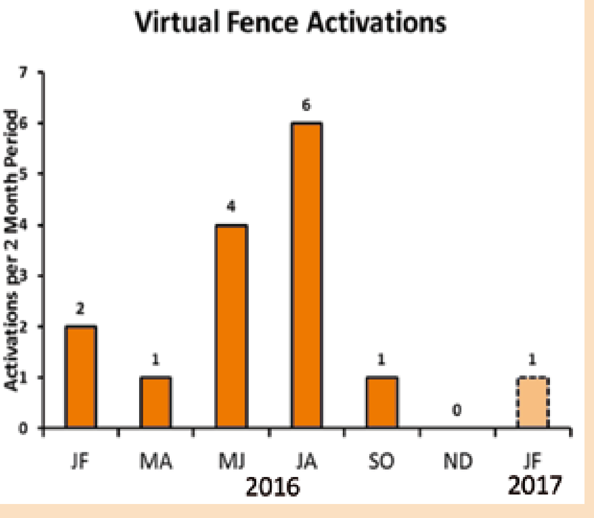

Figure 6.4. **Number of virtual fence activations per two month period from January & February 2016 – January & February 2017. Dotted line indicates activation for a solitary male in January 2017 (from Richardson *et al.*, 2017).**

Virtual fencing is an innovative, new tool that has several management benefits over traditional barrier fences (Jachowski, *et al.* 2014), and is not physically harmful to wildlife. In Australia and the US, conservationists are pushing for more widespread development of virtual fencing, because of its many potential ecological and economic benefits (Umstatter, 2011). Non-human primates are renowned for habituating rapidly to deterrent stimuli (Kaplan & O'Riain, 2015). Nevertheless, after an 18 month trial, the results from Gordon's Bay suggest that virtual fencing is another tool that can potentially be utilised in the protection of livestock against baboons and other predators. However, careful attention must be paid towards utilizing a wide variety of stimuli, whose activation must be highly unpredictable.

Protection collars

Protection collars are plastic or metal collars that protect livestock, most commonly small stock, against neck and throat bites (King, 2006; Snow, 2008). Such collars work on the assumption that when a predator is not able to bite through the collar, it will eventually be discouraged from attacking livestock. Bell and poison collars can also be classified as protection collars, although they are primarily implemented for other purposes (see "Disruptive stimuli" and "Poisons"). There is a lack of scientific evidence on the effectiveness of protection collars to deter livestock predation. Steinset, Fremming & Wabakken (1996) found no significant effect of protection collars against lynx *Lynx lynx* and wolverine *Gulo gulo* predation on sheep lambs in Norway. In addition, some predators are capable of biting through the collars (Snow, 2008) and they are only effective against throat bites (Conover, 2002). In South Africa, questionnaire studies show that livestock farmers often report the use of protection collars (Van Niekerk, 2010; Badenhorst, 2014). However, it is also often alleged that certain South African predators, especially black-backed jackals, become habituated to protection collars and attack the hindquarters when they are unable to inflict a throat bite (Todd, Milton, Dean, Carrick & Meyer, 2009).

Husbandry practices

Fencing

Fencing is generally the first line of defence that is employed to exclude predators from certain areas (Sillero-Zubiri & Switzer, 2004; Kolowski & Holekamp, 2006). Extensive fencing is used effectively in Australia (≈ dingo barrier fence) to exclude dingoes from small-stock producing areas (Newsome, Catling, Cooke & Smyth, 2001; Allen & Fleming, 2004; Clark, Clark & Allen, in Press). Currently, fencing is one of the more preferred non-lethal predation management methods on livestock farms throughout South Africa (Van Niekerk, 2010; Badenhorst, 2014; Schepers, 2016). South African farmers either enclose their entire property, certain areas of their farms (e.g. habitats that are believed to be frequented by predators), or smaller camps for lambing purposes.

For a fence to successfully exclude a predator it is important that it is designed according to the size, strength, and physical agility of the species to be excluded (Fitzwater, 1972; Eklund *et al.*, 2017). In South Africa, it is widely assumed that well-maintained "jackal proof" fencing (wire mesh or closely-spaced wire strand fences, with a minimum height of 1,3 m; Figure 6.5, see following page) is effective at excluding most canids (most notably black-backed jackals – Davies-Mostert, Hodkinson, Komen & Snow, 2007; Smuts, 2008; Viljoen, 2015; PMF, 2016). However, "jackal proof" fencing is less effective at excluding species that are able to climb or jump over fences (Davies-Mostert *et al.*, 2007; PMF, 2016). Despite the prevalence of fencing to deter predators, there have been no scientific studies on their effectiveness at excluding damage-causing predators, or reducing their impacts, in South Africa.

Fencing may be a cost-effective, long-term intervention in South Africa, especially where losses due to predation are high. Nass & Theade (1988) and Perkins (2013), in studies in the US and Australia, respectively, calculated that although the initial input cost of fencing is high, the financial benefits, due to decreased livestock predation and the relatively low maintenance costs of fencing, outweigh the input costs in the long-run in both countries. Maintenance costs in most of South Africa may be higher as the large number of species (e.g. warthog *Phacochoerus africanus,* aardvark *Orycteropus afer*

Figure 6.5. Properly maintained jackal-proof fencing is generally effective to exclude most canid species in South Africa. Photo: Niel Viljoen.

and porcupine *Hystrix africeaustralis*) adept at digging under fences would require frequent and extensive maintenance. There are also negative ecological or environmental impacts associated with fencing. Farmers may lethally control digging species resulting in higher levels of by-catch (Beinart, 1998). This could be countered by the installation of semi-permeable fences (i.e. fences with specially designed gaps installed at intervals) that can allow digging species through and still exclude predators (Schumann, Schumann, Dickman, Watson & Marker, 2006; Weise, Wessels, Munro & Solberg, 2011). However, it is possible that predators may habituate to these fences in the long term.

Fences also have negative ecological impacts by fragmenting the landscape and preventing dispersal of non-target wildlife that perform important ecological roles. There may also be other unintended consequences. For example, in Australia, predators were excluded by fencing from large parts of the country (Newsome *et al.*, 2001; Letnic *et al.*, 2011). Where dingoes were rare, herbivore and fox numbers were higher, which the authors attributed to the meso-predator release hypothesis (≈ smaller predator numbers increase in the absence of larger competing predators) to explain their results (Newsome *et al.*, 2001; Letnic *et al.*, 2011; but see also Allen *et al.*, 2013a). It is possible that similar impacts may occur under South African conditions where large areas are fenced (see Chapter 8). However, true meso-predator release has, to date, not been formally demonstrated in any Australian or African ecosystem (Allen *et al.*, 2013a; Allen *et al.*, 2017).

Night/Seasonal enclosures

Night enclosures (≈ kraals/corrals/bomas) are used to protect livestock at night and seasonal enclosures (≈ shed-lambing or "lambing-camps") are employed to protect vulnerable livestock during the early parts of the lambing or calving season (Knowlton, Gese & Jaeger, 1999; Gese, 2003). Correctly designed kraals, taking into account the predator species against which the livestock are protected (e.g. Howlett & Hill, 2016), are generally seen as effective at limiting predation (Robel, Dayton, Henderson, Meduna & Spaeth, 1981). Kraals have been and are still widely used by subsistence farmers to protect their stock at night (Ogada *et al.*, 2003), including in South Africa (Webb & Mamabolo, 2004; Constant *et al.*, 2015; Hawkins & Muller, 2017). Many commercial cattle and small stock farmers in South Africa also indicate that they employ kraaling (Van Niekerk, 2010; Badenhorst, 2014). It is, however, unknown to what extent kraaling is effective in South Africa as a predation management method. This is an intensive practice with high labour costs (Shivik, 2004). It is also generally less practical as the size of the herd and grazing area increases (Shivik, 2004; Van Niekerk, 2010). Furthermore, kraaling may also negatively affect grazing condition (due to overgrazing, localized concentrations of livestock trampling and increasing nutrient loads through faecal matter), livestock health (diseases may be more easily transmitted under kraaling conditions) and the quality of wool (Snow, 2008). Overgrazing and trampling can be ameliorated by mobile kraaling (e.g. Riginos *et al.*, 2012), but this would require additional labour and expense. Literature from the US suggests that a similar approach to kraaling (lamb shedding) can improve productivity by up to 200%, but it is costly to implement (McAdoo & Glimp, 2000). Overall, the practicalities of mass kraaling on extensive farms, and where large herds are farmed, remain a significant limitation in many parts of South Africa.

Rotational or selective grazing

Livestock predation is often spatially confined and, in such instances, predation could be reduced by excluding livestock from these "hotspots" (McAdoo & Glimp, 2000; Shivik, 2004). Minnie, Boshoff & Kerley

(2015) reported that the majority of livestock farmers bordering the Baviaanskloof Mega-Reserve, Eastern Cape Province indicated that they withdrew their stock from the areas bordering the reserve because of the perceived predation risk. However, the extent to which this strategy decreased predation was not described (Minnie *et al.*, 2015). Furthermore, repeatedly moving livestock can cause stress to the animals and is therefore not always an acceptable approach (Van Niekerk, 2010).

Timing of breeding

Livestock predation often peaks during the lambing or calving seasons or during drier periods when natural prey availability is limited (Tafani & O'Riain, 2017). In such instances, a shift in lambing or calving season so that it does not coincide with either of these events could result in lower livestock predation (Hygnstrom *et al.*, 1994; McAdoo & Glimp, 2000; Snow 2008). Livestock species exhibit seasonal breeding characteristics, but because they are intensively managed, livestock producers have the ability to manipulate the timing of breeding by using contraceptives and/or restricting physical contact between males and females (Gordon, 2017). Some livestock producers in South Africa use this method and indicate that it is effective (Van Niekerk, 2010; PMF, 2016), but it remains to be subjected to formal scientific experimentation. Importantly, as the lambing season is generally the time when most small stock are lost (e.g. Avenant & Nel, 2002; Pohl, 2015), it may be prudent for farmers in a specific region to try synchronise their lambing period as closely as possible to limit the total number of losses in the area. Shifting the timing of breeding may, however, incur undesirable nutritional or productivity costs.

Altering herd composition

The implementation of flerds (mixing sheep or goat flocks and cattle herds) has been shown to effectively reduce coyote predation on sheep but not goats in the US (Hulet, Anderson, Smith & Shupe, 1987; Hulet *et al.*, 1989; Anderson, 1998). McAdoo & Glimp (2000) and Shivik (2004) highlighted various shortcomings with this approach suggesting that it can be a very time-consuming and strenuous process, especially when trying to bond different livestock species. In some areas it can be difficult, or even impossible, to introduce cattle or small livestock because of grazing conditions or topography. Further, where there are larger predators that have the ability to kill cattle, flerding will not be effective. Moreover, predators may become habituated to the presence of the larger livestock (McAdoo & Glimp, 2000; Shivik, 2004). It is sometimes possible to switch to certain livestock breeds that are less susceptible to predation (Greentree, Saunders, Mcleod & Hone, 2000; White, Groves, Savery, Conington & Hutchings, 2000). However, such switching may not always be economically or environmentally viable (Du Plessis, 2013).

Sanitation

There is some scientific evidence to show that carcass removal around livestock operations may reduce the severity of livestock predation (Robel *et al.,* 1981; Hygnstrom *et al.*, 1994). Presumably this is because the removal of potential food resources (≈ animal carcasses), reduces the overall food available to predators in an area (Shivik, 2004). Furthermore, although virtually nothing has been published on this, the removal of livestock carcasses may limit a predator's chances to "learn" to prey on livestock (Avenant, 1993; Avenant & Nel, 2002). There may, however, be constraints for large scale operations with farmers being unable to remove all carcasses (Shivik, 2004). Furthermore, carcass removal will be less effective when the predators implicated are not typically scavengers.

Grazing and natural prey management

Rodents and small game comprise the bulk of the diets of most livestock predators in South Africa (see Chapter 7), as well as in other countries (e.g. Allen & Leung, 2014). It has been suggested that if these natural food sources are preserved on farms, livestock predation could be reduced (Ott, Kerley & Boshoff, 2007; Avenant & Du Plessis, 2008; Du Plessis, 2013; PMF, 2016). It has also been suggested that through appropriate grazing management, by reducing herd size and preventing over-grazing, the habitats where natural prey occur will be less disturbed, resulting in higher prey diversity and numbers (Avenant & Du Plessis, 2008; Blaum, Tietjen & Rossmanith, 2009; PMF, 2016). It is expected that a suitable grazing management strategy will also enable livestock to grow quicker, thereby reducing the potential risk of predation (PMF, 2016). It is, however, also possible that some predators may switch to livestock as their main prey during certain periods of the year, most notably during their reproduction or lactation, and that some individuals may even "learn" to specialize on livestock (Avenant & Du Plessis, 2008; Fleming, Allen, Ballard & Allen, 2012; Du Plessis, Avenant & De Waal, 2015; also see Chapters 7 and 9). Predators also prey on livestock competitors and, in some cases, the benefit of reduced predation may not outweigh the cost of the increased competition arising from the loss of predators (Allen, 2015). These complex predator-prey relationships clearly affect livestock producers, but there remains a limited understanding of how these relationships can be managed to optimise livestock production and conservation goals.

Aversive deterrents

Conditioned taste aversion

Conditioned taste aversion (CTA) is used to repel target species from a specific prey type (Pfeifer & Goos, 1982; Bomford & O'Brien, 1990; Shivik & Martin, 2000; Shivik *et al*., 2003; VerCauteren *et al*., 2003). It entails the use of emetics placed in specific baits, usually carcasses of livestock, and as the predator scavenges on the carcass it becomes nauseous. The nausea is intended to cause avoidance of the prey species (Smith *et al*., 2000). Field studies suggest that CTA has been effective in some cases (Ellins & Catalano, 1980; Gustavson, 1982). However, the majority of the available studies have found the method to be ineffective (Burns & Connolly, 1980; Conover & Kessler, 1994; Hansen, Bakken & Braastad, 1997). Significantly, predators develop an aversion against the baits but continue to kill livestock, presumably because the baits do not successfully mimic live livestock (Conover & Kessler, 1994) and because the predators are able to recognise the taste of the emetic (Strum, 2010). Hansen *et al*. (1997) also observed increased aggressiveness in predators that were exposed to treated baits, which ultimately resulted in a greater intensity of livestock killings. CTA has not been trialled in South Africa, but it is anticipated that it will suffer from similar problems to those experienced elsewhere.

Bio-fencing

Bio-fences (≈ bio-boundaries) are created by strategically placing scent marks or sounds that imitate the presence of conspecifics or other competitors in an area (Anhalt, Van Deelen, Schultz & Wydeven, 2014). These were developed using the same principles as virtual fencing (see Box 6.1). Bio-fences are assumed to deter territorial individuals from entering a demarcated area or force residents to move out of the area (Anhalt *et al*., 2014). The implementation of bio-fences is a relatively new concept (Schulte, 2016) and very little research has been conducted (Robley, Lindeman, Cook, Woodford & Moloney, 2015). Ausband, Mitchell, Bassing & White (2013) found that bio-fences effectively deterred wolves for the first year of study, but not in the second year. In contrast, Jackson, McNutt & Apps (2012) found that artificially placed scent marks resulted in an introduced African wild dog *Lycaon pictus* pack moving away from the periphery of their newly established home-range where the scent marks had been placed. However, Anhalt *et al*. (2014) found that a combination of artificially placed scent marks and foreign howls did not affect the territorial behaviour of wolf packs. In addition, Shivik (2011) found that human-placed coyote urine did not effectively repel coyotes. According to Ausband *et al*. (2013), the success of a bio-fence is influenced by a variety of factors, including *inter alia* the absence of direct conflict between predators, the absence of other signs (e.g. sounds imitating another competing predator) and the longevity of scent marks. It is clear that more research is needed on the use of bio-fencing in general, and specifically in South Africa.

Shock collars

Shock collars can be fitted to individual predators and programmed (or remotely controlled) to deliver an electric shock when the animal engages in a particular behaviour (i.e. attacking livestock) or transgresses a particular spatial boundary (Andelt, Phillips, Gruver & Guthrie, 1999). The technique requires that the predator is successfully captured, collared and released back onto the farm. Some promising results on the use of shock collars as a predation management method have been published (Andelt *et al*., 1999; Hawley, Gehring, Schultz, Rossler & Wydeven, 2009). However, in situations where more common predator species have to be managed the practicalities and costs of collaring large numbers of individuals and re-releasing them onto extensive farming operations makes this technique untenable. In addition, the National Society for the Prevention of Cruelty to

Animals (NSPCA) in South Africa have stated in the past that they do not support the use of shock collars on wildlife as they consider them to be potentially cruel (Cupido, 2010).

Electric fencing

The electrification of existing fences (Figure 6.6) may increase their effectiveness at excluding damage-causing predators, because the predators will tend to avoid being shocked (McKillop & Sibly, 1988; Hygnstrom *et al.*, 1994). Sound construction and maintenance is, however, a prerequisite for electric fences to remain effective. For instance, Clark *et al.* (2005) found that in southeast Georgia in America, the success of black bears *Ursus americanus* in raiding bee-yards was contingent on a fence failure (through depleted batteries) and bear tracks were seen to follow the lines of successful fences, suggesting that bears approach fences but are deterred by an electric shock. However, when bears did cross disconnected electric fences, they consistently did so only a few days after battery depletion, suggesting that they "check" fences regularly. Electric fencing is also used extensively to protect livestock from dingoes in Australia (Bird, Lock & Cook, 1997; Yelland, 2001), and to protect threatened fauna from dingoes and other predators (Long & Robley 2004). In South Africa, Heard & Stephenson (1987) noted that the electrification of an existing "jackal-proof" fence resulted in fewer burrows underneath the fence and hence black-backed jackals were more effectively excluded. In addition, livestock farmers who used electric fencing in Kwazulu-Natal reported that it was generally successful at decreasing predation (Lawson, 1989). Similar results (although unpublished) have been reported in the Eastern Cape (Viljoen, 2015). Game farmers in Limpopo have also indicated that they are generally satisfied and that this measure is effective at limiting losses (Schepers, 2016). In the Western Cape, the use of electric fences is often cited as a successful method for excluding chacma baboons (Hoffman & O'Riain, 2012, Kaplan, 2013).

Electric fencing will likely be a cost-effective method in the long run in South Africa, despite the high costs initially (Viljoen, 2015). However, Beck (2010) found that electric fencing caused the electrocution of at least 33 different mammalian, reptilian and amphibian species across South Africa. In addition, Pietersen, McKechnie & Jansen (2014) found that although some Temminck's ground pangolin *Smutsia temminckii* individuals were not instantly killed by electrocution, due to their long exposure to the electric current they became weak and eventually died from exposure. Nevertheless, it is possible to limit electrocutions from electric fences with appropriate planning and design (Todd *et al.*, 2009).

Figure 6.6. The electrification of an existing fence generally increases its effectiveness at excluding predators. Electric wires close to the ground prevent predators from crawling underneath the fence. Placing wires on each side of the live wire close to the ground may prevent the electrocution of certain non-target animals. Photo: Niel Viljoen.

Provisioning

Supplemental feeding

Although supplemental feeding has been successful in the Cape Peninsula, Western Cape to temporarily distract chacma baboons from raiding urban areas (Kaplan, O'Riain, Van Eeden & King, 2011), it has not been tested extensively in the livestock predation context (but see Van der Merwe *et al.*, 2009). Some game farmers in the North West Province make use of "jackal restaurants" to curb black-backed jackal predation on game species (John Power, 2017, pers. comm.), but the method's effectivness has not been scientifically evaluated. A major concern is that supplemental feeding could increase the fecundity of predators and the territorial behaviour and/

or social structure and diet of the predators may also be altered through provisioning (Kaplan *et al.*, 2011; Du Plessis, 2013; James, 2014; also see Chapters 7 and 9), increasing livestock predation in the long term. For example, Steyaert *et al*. (2014) found that brown bear *Ursus arctos* densities in Slovenia were higher compared to populations in Sweden mainly due to the impact of prolonged supplementary feeding practices in the former country. Consequently, human-bear conflict was also higher in Slovenia. However, Steyaert *et al*. (2014) noted that there could be variations within a population because not all individuals will visit supplementary feeding sites. Nevertheless, providing food subsidies to predators typically also has negative environmental benefits (Newsome *et al*., 2014).

Non-lethal population control

Translocation

Translocation has been used to relocate predators to areas away from the existing conflict. A review by Linnell, Aanes, Swenson, Odden & Smith (1997) and a study by Weilenmann, Gusset, Mills, Gabanapelo & Schiess-Meier (2010) both show that this method is generally only successful when the animal can be relocated to an area with a relatively low density of conspecifics and where the same conflict will not occur (i.e. absence of species the predator was targeting). If these requirements cannot be satisfied, the translocated predator will likely disperse from the release site, sometimes back to the original site of conflict and/or the problem will merely be transferred to a new area. There is currently no scientific information on the usefulness of translocation to manage livestock predations in South Africa, although there are various groups actively involved in "rescuing" and translocating apparently damage-causing predators (e.g. CapeNature, 2017). A single study has shown the successful translocation of a leopard away from the conflict area (Hayward, Adendorff, Moolman, Dawson, & Kerley, 2007), but the consequences for livestock predation in this case are unknown. Monitoring the outcomes of these translocations is needed. It is prescribed by law that a permit to translocate a damage-causing animal in South Africa can only be issued once it has been shown that all other management interventions have been exhausted (NEMBA, 2004).

Fertility control

Fertility control includes interventions such as contraception and sterilization, and is employed to decrease birth rates (Shivik, 2006). Bromley & Gese (2001a) found that surgical sterilization of entire coyote packs in the US successfully reduced small livestock predation, presumably because coyotes kill more livestock when pups are present. Knowlton *et al*. (1999) envisaged that contraceptives could have a similar effect in coyote populations. Bromley & Gese (2001b) noted that surgical sterilization did not affect coyote territoriality or social behaviour. Similarly, in Saudi Arabia the sterilization of male hamadryas baboons *Papio hamadryas* did not alter troop composition and social structure for four years after sterilization (Biquand *et al*., 1994). In addition, during those four years, only one male dispersed into another troop (Biquand *et al*. 1994). The latter study, however, was conducted to test the effect of fertility control on the raiding behaviour of hamadryas baboons and not livestock killing behaviour.

Despite the demonstrated effectiveness of fertility control to manage some predator populations, there are several limitations. If factors other than the presence of offspring influence livestock predation patterns, then fertility control may not be effective at reducing livestock killings (Knowlton *et al*., 1999; Bromley & Gese, 2001a). Furthermore, fertility control can be time consuming and costly. In most cases it is impossible to identify the breeding individuals in a predator population and, as such, the successful application of fertility control would require the capture and sterilization or the application of contraceptives to all adults of one sex within a target population (Mitchell, Jaeger & Barrett, 2004; Shivik, 2004; Connor, Ebinger & Knowlton, 2008). Significantly, there are no species-specific contraceptives available that could be applied to baits , raising concerns around possible impacts on non-target species (Gese, 2003). Currently, no scientific evidence is available on the use of either contraception or sterilization for damage-causing predators in South Africa and given the broad distribution of many of the damage-causing predator species and their large numbers this method is highly unlikely to have application outside of small, isolated areas.

Producer management

Compensation schemes

Compensation is generally implemented to reduce the persecution of less common or protected species that kill livestock (Bulte & Rondeau, 2005; Rajaratnam, Vernes & Sangay, 2016). Although there are examples of compensation schemes that have successfully decreased retaliatory killing of predators (e.g. Bauer, Muller, Van der Goes & Sillero-Zubiri, 2015), a number of studies (Bulte & Rondeau 2005; Lamarque *et al.* 2009; Rajaratnam *et al.* 2016) highlighted shortcomings associated with compensation schemes. When compensation schemes are available, producers may reduce effort in protecting their stock. Consequently, livestock losses may actually increase (although it is possible to counter the latter behaviour – see Bauer *et al.*, 2015). It is also often difficult to monitor or verify predation claims or whether producers are complying with any terms associated with a specific compensation programme and thus the system may be abused. Compensation could be paid out irregularly, especially in developing countries, due to budget constraints. It could be difficult for less literate or isolated farmers to claim. People may be discouraged from claiming compensation because of the time and cost involved in the process (Bulte & Rondeau, 2005; Lamarque *et al.*, 2009, Rajaratnam *et al.*, 2016). In general, if compensation schemes are well administered and resourced, and measures are in place to successfully monitor and confirm claims of predation, the method may have some potential to limit persecution of rarer carnivore species (e.g. cheetahs, leopards). However, compensation is unlikely to be economically feasible where livestock predation is caused by more common species (e.g. black-backed jackals, caracals). Overall, compensation will ultimately only shift the economic costs of livestock predation from livestock producers to governments, conservation entities or the taxpayer and will not resolve livestock predation (i.e. compensation provides a viable conservation tool but an unfeasible tool to reduce livestock predation).

Insurance programmes

Insurance programmes rely on livestock owners paying a premium on a fixed basis that enables the contributor to be refunded in the event of losses due to livestock predation (Madhusudan, 2003). Although insurance programmes can be successful for farmers where herds are relatively small and where livestock predation is relatively low (e.g. Mishra *et al.*, 2003), it is anticipated to be less feasible for larger livestock enterprises or where livestock losses are high (Du Plessis, 2013). This is because it is often difficult to monitor or verify the cause of livestock mortality with the consequence that most livestock losses, particularly of young, are categorised as unknown. Ultimately the lack of accurate information on depredation rates and the variable success of different methods to mitigate predation may make it difficult for insurance companies to develop viable insurance models/plans (Du Plessis, 2013). Clearly work is needed to overcome these limitations.

Financial incentives

Bounties are generally used as a measure to control invasive or "problem-causing" species. People are paid for every individual hunted (see Lethal Predator Management section) of a species that are considered undesirable (Neubrech, 1949; Hrdina, 1997). Although this measure has been used extensively in the past as a predation control method by various governments throughout the world, it has been abandoned by many (e.g. Neubrech, 1949; Beinart, 1998; Schwartz *et al.*, 2003). It is still officially implemented in some countries (e.g. Australia, Canada, US) but there is a growing consensus that it is not an effective predation management method (Glen & Short, 2000; Pohja-Mykra, Vuorisalo & Mykra, 2005; Proulx & Rodtka, 2015). Furthermore, as highlighted by the current chapter, various environmental and ethical concerns arise where bounties are used to reduce predator numbers.

Trophy hunting of damage-causing species or individuals is sometimes proposed as another form of financial incentive to reduce predation. The basic premise of this strategy is that if livestock owners have the opportunity to hunt a known damage-causing species or individual that occurs on their property, and receive the income from this, they will become more tolerant of the species (Treves, 2009). However, in cases where a permit needs to be granted to hunt a specific damage-causing individual, it may be difficult to identify the culprit (Treves, 2009). Furthermore, it might be difficult to verify damages caused by a specific individual and hence the approach could be subject to fraudulent claims (Treves, 2009). It is also possible that the economic benefits may only accrue to selected individuals (Dickman, Macdonald & Macdonald, 2011). Hunting may also have unintended social disruptions in the local predator population, which could lead to an increase in livestock predations in the long term (Treves, 2009; Peebles *et al.*, 2013; Loveridge *et al.*, 2016; Teichman *et al.*, 2016; also see "Shooting").

Financial incentives can also be implemented directly through the payment of subsidies/tax rebates or indirectly through the development of "predator friendly" brands. The main aim of these two measures is to motivate producers to implement or commit to certain predation management methods (Mishra *et al.*, 2003) and thus they are not considered to be predation management *per se* (similar to laws and regulations – see Box 6.2). Nevertheless, it can be used as an important economic tool which may assist in overall predation management. Historically, government subsidies were widely offered to livestock producers in South Africa to implement certain predation management methods (Beinart, 1998), but this is no longer the case. More recently, some "predator friendly" branding has also been proposed in South Africa (Avenant, De Waal & Combrinck, 2006, Smuts, 2008). When livestock owners subscribe to such a brand, they commit to implement only certain (generally non-lethal) predation management methods (Treves & Jones, 2010). Such an approach theoretically enables producers to charge a premium for their products and thereby offset the potential costs associated with the implementation of the prescribed predation management methods (Smuts, 2008). Although "wildlife friendly" brands have been implemented successfully before in subsistence communities (Marker & Boast, 2015), there are some questions regarding its use in commercial settings in South Africa. Notwithstanding the major issue of regular compliance monitoring in extensive areas (Treves & Jones, 2010), "wildlife friendly" branding is a marketing tool which targets more wealthy consumers. "Predator friendly" branding may thus not succeed as a viable financial incentive for the majority of commercial livestock producers.

Box 6.2 The role of laws and regulations in livestock predation management

Predation management is widely guided by various laws and regulations which attempt to control how certain predation management methods are applied, or to force producers to not use certain methods or not to kill certain species (also see Chapter 5). Although these laws and regulations will presumably be successful in most cases to control predation management, there are examples in South Africa where laws pertaining to wildlife management have been successfully challenged and annulled by the courts because they lacked adequate scientific evidence [e.g. SA Predator Breeders Association vs. Minister of Environmental Affairs (72/10) ZASCA 29 November 2010]. There are also examples where stakeholders disregard certain laws (e.g. the regulations placed on the use of poisoning as a predation management tool) out of desperation, or because they feel that these regulations threaten or exclude their interests (Du Plessis, 2013). The unlawful use of certain prohibited methods on livestock farms in South Africa is exacerbated by the extensive nature and remote location of these farms, which often complicate law enforcement. Furthermore, when predation management laws and regulations become overly prescriptive farmers may feel that they do not have any control over management decisions, and this may influence how and what predation management methods they implement. For instance, Lybecker, Lamb & Ponds (2002), Kleiven, Bjerke & Kaltenborn (2004) and Madden (2004) noted that when certain wildlife species were protected, and their management regulated by excessive laws on private land, landowners felt that they lost control over what happened on their land. This contributed to these farmers developing a dislike towards the protected wildlife and the prescribed management methods. Similarly, Bisi, Kurki, Svensberg & Luikkonen (2007) and Bath, Olszanska & Okarma (2008) found that people showed more dislike for specific species once they were instructed on how to manage these species.

Lethal predator management

Shooting

Shooting is generally applied in two ways. Firstly, it is intended to decrease the risk of predation by reducing overall predator numbers in an area, either by shooting predators opportunistically or through concerted killing operations (Hygnstrom *et al*., 1994; Mason, 2001). Secondly, shooting is used to eliminate damage-causing individuals in a specific area after a livestock predation event (Hygnstrom *et al*., 1994; Reynolds & Tapper, 1996; Mitchell *et al*., 2004). In South Africa, shooting, in conjunction with calling, is often employed at night to control black-backed jackals (Snow, 2008; Figure 6.7). Currently, shooting is the most frequently reported predation management method across all types of livestock farms in South Africa (Van Niekerk, 2010; Badenhorst, 2014; Schepers, 2016), which can often be linked to its recreational value. Despite its popularity amongst farmers there is only limited scientific information on its efficacy in South Africa.

When shooting is used, population reductions are generally considered a species-selective method because only individuals from the target species are shot. The method has been used to effectively decrease coyote and lynx predation on sheep in the US and Norway, respectively (Wagner & Conover, 1999; Herfindal *et al*., 2005; Connor *et al*., 2008). These successes were due to some (or most) of the individuals responsible for livestock killings being removed. However, in a questionnaire study conducted on livestock farmers in Kwazulu-Natal, one of the respondents reported that over a period of three years, despite shooting black-backed jackals every year (between 39 and 54 jackals annually), he continued to lose more than 100 sheep a year (Humphries *et al*., 2015; also see Thomson, 1984). Additionally, Minnie *et al*. (2016) in a study on the effect of extensive shooting on black-backed jackal populations on livestock farms in the Eastern and Western Cape, found that jackal populations on these farms were generally younger and more unstable compared to populations on nearby reserves. This was because sustained shooting on the farms resulted in the disruption of the normal, mutually exclusive territorial system of black-backed jackals and created vacated areas for younger dispersers. Minnie *et al*. (2016) also demonstrated that the populations on the farmland compensated for population reductions by reproducing at a younger age and by carrying more foetuses (also see Loveridge, Searle, Murindagomo & MacDonald, 2007; Chapter 7). Minnie, Zalewski, Zalweska & Kerley (2018) also showed that shooting created

Figure 6.7. A variety of devices are commercially available that can be used to call and shoot black-backed jackals in South Africa. It is widely believed that the unselective and incorrect use of this method may have, however, contributed to exacerbate livestock predation in South Africa. Photo: Niel Viljoen.

source sink populations, with jackal recruiting into areas with control through shooting, with both reserves and other livestock farms serving as sources.

However, in the US, Wagner & Conover (1999) maintained that aerial gunning (≈ shooting from fixed-wing aircraft) of coyotes during the winter to control predation on sheep decreased the effort for predation management during the following summer. Resultantly, the authors contended that the financial benefits of this approach outweighed the costs by 2.1:1. The costs and benefits of aerial hunting may vary depending on several factors, including the type of aircraft used, experience of the pilot and aerial hunter, size of the area hunted, topography, density of foliage, predator species targeted and weather conditions (Wagner & Conover, 1999). Collectively culling black-backed jackals on an annual basis via helicopter by groups of small stock farmers, generally in the months preceding lambing, is a widespread practice in many parts of South Africa (N. Avenant, 2017, pers. comm.). Although farmers claim that the collective hunts reduce their livestock losses significantly, to date it has not been quantified how cost-effective these operations are in the long term.

Shooting used in conjunction with calling is generally considered a relatively inexpensive, species selective and effective way to reduce predation in the short-term (Reynolds & Tapper, 1996; Mitchell *et al.*, 2004). In a study in the US, calling has been shown to attract more male coyotes than females, presumably because they are the main defenders of territories (Sacks, Blejwas & Jaeger, 1999). Calling has also been noted to successfully attract breeding coyotes (≈ the individuals which generally kill more livestock), presumably because of their need to defend their litters (Sacks *et al.*, 1999). Knowlton *et al.* (1999) concluded that if calling is restricted to the areas where predation occurs, it could be used effectively to attract damage-causing coyotes. However, despite the observed successes, Windberg & Knowlton (1990) noted that calling in their study area attracted more juvenile coyotes and they believed this was due to an avoidance behaviour which was developed in the older individuals. Although some in South Africa claim that calling and shooting is successful at reducing black-backed jackal numbers (Du Plessis, 2013), there is a lack of scientific information in this regard. There is also consensus that where calling and shooting is applied incorrectly and indiscriminately, it will result in habituation (N. Viljoen, 2017, pers. comm.).

Denning

Denning involves the killing of young predators at their dens without killing the adults. It is based on the same assumption as reproductive interference, which is that by removing the young, there will be a decrease in depredation because the adults no longer need to provision their young (Hygnstrom et al., 1994; Gese, 2003). Till & Knowlton (1983) showed the effectiveness of denning for controlling coyote predation on sheep in Wyoming, US. In this instance, incidences of predation on livestock decreased by 87.7% and total livestock kills decreased by 91.6% after the removal of the pups. Gese (2003), however, noted that den detection can be very time consuming depending on, amongst others, the cover and terrain, although domestic dogs could potentially be trained to detect dens. Denning also requires annual implementation and provides only a short-term solution (≈ less than 12 months). Furthermore, if factors other than litter presence influence livestock predation patterns, denning will not necessarily be effective (Till & Knowlton, 1983). Denning may potentially also trigger compensatory breeding in certain predators (see Loveridge et al., 2007; Minnie *et al.*, 2016).

Hunting dogs

Although it is possible for a well-trained hunting dog pack to be selective, hunting with dogs is generally perceived to be non-selective and unethical (Smuts, 2008; Snow, 2008). The selectivity of this method may increase if employed soon after a predation event and at the predation site (Snow, 2008). Dogs have been used extensively in the past to capture predators in South Africa (Hey, 1964; Rowe-Rowe, 1974; Pringle & Pringle, 1979). However, it is currently illegal in South Africa for dogs to capture a predator although they can still be used to chase or point (≈ dogs search for the target and bark when they find it) at the predator (NEMBA, 2004). Hey (1964) demonstrated that seasonality, climatic conditions and topography can all influence the successfulness and specificity of dog hunts. Further, based on an interpretation of the information obtained from historical hunting records in South Africa, the efficacy of dog hunts is questionable (Gunter, 2008). According to

Gunter (2008), when hunting clubs used dogs to remove predators, neither predator numbers nor livestock predation decreased considerably. This was attributed to climatic conditions, the fact that hunters sometimes pursued predators long after damage was reported, and the capability and motivation of hunters. However, Gunter (2008) did caution that drawing conclusions from such historical data may be limited owing to the incomplete nature of the data. Overall, hunting dogs may be a good option to track damage-causing predators in certain conditions (e.g. in mountainous or bushy terrain), but then it is important to ensure that the dogs are well trained and under the control of a competent handler. It remains, however, crucial to gather more information on the efficacy of this method.

Poisons

Poisoned baits are considered highly unselective and their use is outlawed in many countries (Sillero-Zubiri & Switzer, 2004), including South Africa (PMF, 2016). In South Africa, poisoned baiting is generally applied by strategically placing a treated livestock carcass or a piece of bait in the field (e.g. at burrows dug under a border fence) or by scattering treated pieces of meat where predator activity is visible (Snow, 2008). To target baboons, poisoned bait is placed in a plastic bottle or small container that can only be accessed and opened by primates through manipulation or biting (M. Tafani, 2017 pers. comm.). There is not much scientific information on the effectiveness of this method to decrease livestock predation in South Africa. However, in other countries, poisoned baiting has been shown to be successful at decreasing the population sizes of some predators (Gunson, 1992; Eldridge, Shakeshaft & Nano, 2002; Thomson & Algar, 2002; Burrows *et al.*, 2003; Allen, Allen, Engeman & Lueng, 2013b). However, Gentle, Saunders & Dickman (2007) found that the numbers of more common species, such as European red foxes, recovered quickly due to immigration. Eldridge *et al.* (2002) also noted that despite a decline in dingo densities initially, there was no difference in damage to cattle between poisoned and un-poisoned areas in Australia. Consequently, the authors concluded that most of the damage-causing individuals were not affected by these baits, presumably because they did not utilize them as food sources (Eldridge *et al.*, 2002; 2016). It is alleged that some black-backed jackal individuals may show similar avoidance behaviour towards poisoned baits (Snow, 2008). Nevertheless, the most significant issue with respect to poisoned baiting in South Africa remains its unselective nature (Figure 6.8). For example, the Wildlife Poisoning Database of the Endangered Wildlife Trust (EWT) lists 174 individual incidents of poisoning of non-target raptor species in South Africa resulting in 2023 mortalities (A. Botha, 2017, pers. comm.).

Figure 6.8. One of the most significant issues with respect to poisoned baiting in South Africa remains its unselective nature. Scavengers are especially at risk to this method. Photo: André Botha.

The coyote getter or M44 (the latter is a modification to the original coyote getter) is a mechanical device with a cartridge that ejects a poison (generally in the mouth) when a trigger is pulled by a predator (Blom & Connolly, 2003). Compared to poisoned baiting, "getters" can be considered a more acceptable method because *inter alia*: (1) the "getters" are more selective (≈ an animal has to trigger the "getter" for the poison to be released) (2) the poison is secure and cannot be carried away by an animal; and (3) the poison degrades slower in "getters", because it is protected in the cartridge from the elements, and thus yields a lethal dose for longer. In South Africa, it is currently illegal to use traditional forms of "getters" because these devices use ammunition (PMF, 2016). Furthermore, the method is widely outlawed of because of its perceived non-selectiveness and the potential environmental impact of the poisons used (Sillero-Zubiri & Switzer, 2004; Snow, 2008). However, Marks & Wilson (2005) have demonstrated that it is possible to make these devices more species-specific. Bothma (1971) tested the efficiency of coyote getters to kill black-backed jackals over a 60 day period in the former Transvaal and found that almost 80% of all triggers caused by black-backed jackals occurred within the first 14 days, thereafter the trigger rate gradually decreased until almost no triggers occurred in the last 20 days. However, only 45% of the coyote getters that were triggered successfully killed black-backed jackals (Bothma, 1971). Brand, Fairall & Scott (1995) and Brand & Nel (1997) studied the avoidance behaviour of black-backed jackals towards these devices. The two studies both found a capture bias towards younger individuals, with older individuals showing avoidance behaviour. Sacks *et al*. (1999) observed a similar bias in coyotes and concluded that M44's would not be effective at controlling coyote depredation since it is usually the older, breeding coyotes that are responsible for most livestock killings. Importantly, the ability of certain damage-causing predators to avoid coyote getters, together with them being able to be activated by several African fauna species, make these devices problematic in the South African context.

Poison collars (≈ collars with pouches that contain a lethal dose of poison; Figure 6.9) only target predators that attack livestock (Mitchell *et al*., 2004). These collars are often considered an effective and more ethically acceptable alternative to removing damage-causing individuals that evade other control methods (Gese, 2003; Sillero-Zubiri & Switzer, 2004; Smuts, 2008; Snow, 2008). Poison collars have been successful at controlling coyotes in the US under experimental conditions (Connolly & Burns, 1990; Burns, Zemlicka & Savarie, 1996). Connolly & Burns (1990), in field tests in the US, also recorded a puncture rate by coyotes into poison collars of 43%. It was, however, not clear how many coyotes were killed in the latter experiment. Blejwas, Sacks, Jaeger & McCullough (2002) found poison collars to be the most effective method to reduce sheep losses compared to non-selective methods and instances where no predation management efforts were implemented. Burns *et al*. (1996) further showed that the coyotes in their pen tests did not show any aversive behaviour towards poison collars. Despite its apparent successes, accidental spillages of poison from the collars could kill livestock (Burns & Connolly, 1995), and scavengers can be affected when they eat predator carcasses (Burns, Tietjen & Connolly, 1991; Snow, 2008), although this can be prevented to an extent by using certain poisons and specific dosages. In South Africa, Avenant, Steenkamp & De Waal (2009) demonstrated that the use of poison collars, in combination with the use of non-lethal methods (bells, stock management, and range management), on a farm in the Western Cape was effective at reducing caracal predation on sheep. Importantly, to inhibit habituation, the poison collars were fitted to stock only when a loss to a caracal occurred and removed as soon as the losses stopped (Avenant *et al*., 2009). To use poison collars in South Africa, a valid permit is required and only sodium mono-fluoroacetate (≈ Compound 1080) can be used (NEMBA, 2004).

Figure 6.9. Toxic collars are generally considered a very target-specific method and the safest application of poison. Photo: Niel Viljoen.

Trapping

Trapping generally intends to capture a predator alive, although under most circumstances in South Africa, the target predator is killed after it has been trapped. A variety of traps exist, including cage traps, foothold traps, snares or killer traps (Figure 6.10). The former three traps are generally used in conjunction with a lure to attract the target species. In general, trapping is likely to be very specific for solitary felids that cache and return to their kills (e.g. caracals, leopards) if the trap is set at the kill site. Cage traps can be selective and humane if non-target species are released and traps are checked regularly. Brand (1989) demonstrated the effectiveness of cage traps for capturing caracals and chacma baboons in the former Cape Province and noted that it is a relatively inexpensive method for capturing predators. However, Brand (1989) did not test the effectiveness of cage traps to reduce livestock predation. Thus, it is not possible to determine the cost-effectiveness of this method. A major disadvantage of cage traps and all methods of trapping is that it is not possible to know whether it is the specific damage-causing individual that has been caught (but see earlier in this paragraph), and they require considerable effort to bait and check on a regular basis.

Figure 6.10. The use of traditional indiscriminate traps like the killer trap (left) will be difficult to motivate from an environmental or ethical perspective, while it may be more acceptable to implement modified traps (right) that will likely cause less harm to a captured individual or that are more species selective. Photos: Niel Viljoen.

A leghold device consists of two interlocking steel jaws that are triggered when an animal of sufficient weight steps on the trigger plate. The use of leghold devices (especially the older gin traps) is also often strongly challenged because they are viewed as non-selective and inhumane (Smuts, 2008). Although some evidence exists to show that this method can be effective to capture certain damage-causing predators in South Africa (Rowe-Rowe & Green, 1981; Brand, 1989), it is not clear whether this method alleviates livestock losses. According to an unpublished survey by the EWT, 50% of respondents who indicated that they used gin traps (64 of the total number of respondents) reported that they captured non-target species (Snow, 2008). In addition, although studies by Rowe-Rowe & Green (1981) and Brand (1989) found that gin traps were effective in capturing black-backed jackals and caracals, the traps were relatively unselective and also captured non-target species. It has been suggested that the species selectivity of foothold traps (and possibly also other forms of traps) could be improved by the correct calibration of the traps and the selection of the correct lure (N. Viljoen, 2017, pers. comm.). Indeed, McKenzie (1989) and Kamler, Jacobsen & MacDonald (2008) showed that specially modified traps captured fewer non-target species and caused limited injuries to the captured individual. Currently, only foothold traps with offset and/or padded jaws (≈ soft traps) are permitted in South Africa (NEMBA, 2004).

Three types of snares exist, namely body-, neck-, or foot-snares (Gese, 2003; Turnbull, Cain & Roemer, 2011). The former two consist of a looped wire cable which tightens around the body or neck once the animal passes through it and thrusts forward. These snares are generally set at a hole under a fence where predators pass through, along pathways or at den entrances. Foot snares are set on the ground, generally in pathways, and when an animal steps on the trigger, the cable is released and tightens around its foot (Logan, Sweanor, Smith & Hornocker, 1999; Gese, 2003). Because of their relative simplicity, low cost and ease of handling, neck snares are often used in the US to control damage-causing predators (Gese, 2003; Turnbull *et al.*, 2011). However, snares are also viewed as non-selective and inhumane by some groups (Smuts, 2008). The selectivity of snares can be increased with the addition of break-away locks or stops, setting at the height of the target species, or for foot snares by adjusting the sensitivity of the trigger plate (Frank, Simpson & Woodroffe, 2003; Turnbull *et al.*, 2011).

Unlike other forms of trapping, a killer trap (≈ "doodslaner") intends to kill the captured animal. It is uncertain to what extent this device is still used in South Africa. It is usually placed at an opening under a fence and when a predator (or other animal) pass through, the device is triggered and impacts the animal on its head or body. The force of the device generally kills the captured animal or cause severe injuries (Ramsay, 2011). Although there is no scientific information on the use of this device, its indiscriminate nature will likely make it an untenable option.

INTEGRATION OF METHODS WITHIN AN ADAPTIVE MANAGEMENT FRAMEWORK

The preceding section on Predation Management Methods discusses the different predation management methods that are used both globally and in South Africa. While the lack of appropriately designed research to test the short and long-term efficacy (and side-effects) of each method precludes prescriptive assignment for particular predator problems, there is a growing acceptance among both scientists (Hygnstrom *et al.*, 1994; Knowlton *et al.*, 1999; Avenant *et al.*, 2009; Du Plessis *et al.*, 2015; Eklund *et al.*, 2017) and professional predation managers (De Wet, 2006; PMF, 2016) that management needs to be adaptive and draw on different methods depending on the local context (also see Box 6.3). Reasons for this perspective include the following insights (although the list is not exhaustive):

1. Unselective lethal management: The removal of territorial dominant individuals encourages the influx of dispersing, non-territorial individuals (Loveridge *et al.*, 2007; Avenant & Du Plessis, 2008; Minnie *et al.*, 2016) that could negatively impact the density of natural prey (Avenant & Du Plessis, 2008; Avenant *et al.*, 2009) and could be more prone to predate on "unnatural" prey (i.e. livestock) (Avenant, 1993; Avenant *et al.*, 2006).
2. Confounding variables: Particular combinations of methods may be counterproductive (Hygnstrom *et al.*, 1994; N. Avenant, 2017, pers. comm.; N. Viljoen, 2017, pers. comm.). For example, the simultaneous removal of predators and the introduction of LGDs. LGDs are hypothesised to be successful because they prevent predation by keeping predators away from livestock flocks or herds (Allen *et al.*, 2016). Presumably, if the farmer ceases to implement lethal control after the introduction of LGDs, predators will generally remain in the larger area and only avoid the area/camp/part of the camp where the LGD is present (≈ they do not leave the farm/abandon their territory). However, if lethal removal of predators continues, immigration of other predators may still occur, with short term increases in densities, territorial disputes, less natural prey, and potentially more livestock losses (see above). LGDs may also be susceptible to the predator removal techniques. In this example, a combination of LGDs and the lethal removal of predators may not only be counterproductive, but confound the efficacy of either method. The net outcome in this example is to erroneously dismiss LGDs as a potentially viable management option.
3. Scalability: A non-lethal method may be successful at the scale of an individual camp or farm, but ineffective at the landscape level within an entire district with hundreds of farms. In such cases, a method may simply deflect predators to other areas and regional losses may be similar or higher due to immigration. In instances where an animal is conclusively shown to prefer livestock and could be removed with a highly selective

lethal method then this might be preferable to a non-lethal method that merely deflects it to a neighbour, thus exacerbating their livestock losses.

4. Habituation: Given the learning capacity of mammals in general and social carnivores in particular (Box & Gibson, 2009), the overuse and misuse of specific methods may greatly increase the rate at which predators habituate to them (see "Predation management methods"). It is thus essential for the effectiveness of specific methods to be carefully monitored and disused before predators habituate to them. This can be achieved by frequently changing methods to maintain high levels of unpredictability and aversion in the landscape that livestock frequent.

Currently, there is limited scientific information to demonstrate the value of integration of different predation management methods in South Africa (Avenant *et al*., 2009; Du Plessis, 2013; McManus *et al*., 2015). Avenant *et al*. (2009) demonstrated how a combination of rangeland management practices (≈ management of the natural prey base), livestock management practices (≈ lambing in designated camps; regular and continuous flock monitoring and moving; removal of carcasses), preventative non-lethal predation management methods (≈ bells, protection collars) and selective lethal predation management methods (≈ poison collars) were integrated and interchanged effectively to decrease damages by caracal on a sheep farm in the Beaufort-West district, Western Cape. In this instance, Avenant *et al*. (2009) confirmed that caracal predation could largely be prevented with non-lethal methods used in such a way so as to prevent habituation. It is accepted that in some cases lethal alternatives may have to be used to remove damage-causing individuals that are not deterred by preventative methods (Viljoen, 2015, PMF, 2016; Viljoen, 2017).

Box 6.3 Adaptive management recommended to farmers in the absence of a clear, scientifically informed management strategy

In the early 1900s to mid-1990s, many livestock owners in the then Cape province relied on government subsidised jackal proof fencing together with guarding animals such as donkeys, Ostrich and cattle to limit losses to predators. If farmers became aware of localised damage they typically responded by concentrating predator management efforts in that specific area. Methods included walk-in traps, gin traps, coyote-getters and chasing with dogs/shooting (Beinart, 1998; De Wet, 2006; Stadler, 2006). This approach integrates preventative (exclusion with fencing) and retaliatory (both lethal and non-lethal) methods. It also relied heavily on the constant patrolling of fence lines, stock counts and looking for spoor and other signs (e.g. scat) of "problem animals". A change in management actions following an observed change in losses or predator presence is an excellent example of adaptive management which filled the vacuum created by the absence of robust and systematic scientific research. Importantly, constant communication between neighbours and communities lead to similar methods being practised over very large areas and the net effect was an effective predation management system built on local knowledge, professional opinion and advice from predator management efforts around the world.

In the last *c*. 50 years the socio-political and ecological environments have changed markedly in South Africa, which can be seen in the levels of livestock losses and current farming methods. Changes in labour law, land claims, minimum wages and reduced subsidies to farmers (see Chapter 2) have translated into less "feet on the ground" as more farmers farm with less workers on more than one farm. In addition there are important landscape-level changes apparent in farming regions including many farms belonging to "weekend farmers" (less monitoring and predation management), and more game farms, state conservation, forestry and mining areas, all with different damage-causing animal management needs. In addition, jackal proof fences are old and dilapidated in many areas and not capable of limiting the movement of dispersing predators onto farms. Together these factors are generally perceived to have impeded coordinated and landscape level adaptive management strategies necessary to thwart predators. Thus, despite the fact that many more management methods have become available (see Table 6.1), both the number of stock losses and the number of damage-causing animals have apparently also increased, and farmers are today more frustrated with the situation than ever before (Du Plessis, 2013). Many professional predation managers and farmers are of the opinion that the incorrect application and integration of methods are at least partially to blame for the escalating livestock losses (see Avenant & Du Plessis, 2008). Although virtually nothing has been published in South Africa on this topic in scientific papers (see Du Plessis, 2013; McManus *et al.*, 2015), these practitioners still agree that combinations of both preventative and retaliatory methods, with definite time periods and set intervals, should be used. This approach has international support, including the USDA National Wildlife Research Center in the US (Hygnstrom *et al.*, 1994; Knowlton *et al.*, 1999), and in Australia (Anon. 2014).

Neither the notion of striving for the single "silver bullet" method nor using the entire toolbox (see section on Predation Management Methods) simultaneously are currently supported. For farmers commencing with predation management, professional opinion is that a well-constructed and maintained predator fence around high risk areas, such as lambing camps, is an essential first step towards managing your livestock and predators. In deciding which other methods to use thereafter the farmer, in consultation with a professional, should consider the geography of the farm and which habitats and hence camps will be preferred by which predators, the life history and behaviour of the predators in the general area and the diversity, distribution and availability of the natural prey. Before applying any specific method(s) the goal and likely outcomes should be communicated to neighbouring property owners as there will likely be direct (≈ predator displaced to their farm) or indirect (≈ more competition from wild herbivores for forage) consequences of the action. If a farmer/manager observes that a method is no longer effective it should be withdrawn immediately and withheld in the short term to avoid habituation. When unacceptably high losses can be ascribed to predators, the most appropriate retaliatory methods should be used with reference to the behaviour of the target species and the relative success and welfare considerations of the different methods (e.g. cage traps for caracal but with cages checked at least once daily). Both lethal and non-lethal methods should be considered, with the aim always to prevent the specific damage-causing individual(s) from accessing livestock. In a situation where exclusion fencing is well constructed and maintained, the number of predators gaining access to that specific area (e.g. the lambing camp) will be small. Hence any lethal management within the camp (e.g. call and shoot) is likely to target a damage-causing individual and greatly reduce losses in the short term. Intimate knowledge on the predator's biology, behaviour and the probability of them habituating to a specific method are critical components of the selection, application and withdrawal of a specific method or combination of methods. The effective monitoring and understanding of the specific farm system and the broader ecosystem that it occurs in are also critically important components of a successful predation management strategy.

CONCLUSION

A variety of management methods are available to counter predation on livestock. From our assessment, it is evident that most of these methods have been used or trialed in one form or another in South Africa. However, the biggest issue is the paucity of reliable, experimental data (see Box 6.4) on their overall efficacy internationally (see Treves *et al.*, 2016; Eklund *et al.*, 2017), and the fact that little has been done in the South African context, which means that it is not possible to scientifically accept or refute any specific method. This is not to say that these predation management methods are ineffective, but that we cannot tell if they are or not given the lack of robust data. In most cases, predation management in South Africa is therefore currently based on a combination of personal experiences and educated guesswork (Avenant & Du Plessis, 2008; Minnie, 2009; Du Plessis, 2013).

Box 6.4 Understanding the scientific value of different information sources

A relatively large pool of publications on predation management, as discussed in this chapter, is available to draw information from. However, it is important to understand the shortcomings that are associated with the different information sources.

Anecdotal information: Anecdotal information generally describes personal experiences and in most cases lacks any level of scientific scrutiny. This type of information should thus be used with caution. However, in some cases anecdotal publications may provide some valuable insight on a specific topic. In such cases, it may prove valuable to validate other sources of information or to highlight relevant research topics (NRC 2004).

Theses, dissertations and semi-scientific (quasi-scientific) information: Although these types of publications often follow some sort of peer-review process, they are generally not exposed to the same level of scientific scrutiny as peer-reviewed publications. Furthermore, it is likely that the research culminating into these publications follows some form of recognized research methodology or standard. In many instances, the results of theses, dissertations or semi-scientific publications are not followed through to peer-reviewed publication. However, the results could still provide valuable information which is often the only information source on a specific topic (Du Plessis *et al.*, 2015).

Peer-reviewed information: Peer-reviewed publications are (generally) subjected to rigorous scientific scrutiny and are generally recognised as a credible source of information. However, Treves *et al.* (2016), Eklund *et al.* (2017) and Allen *et al.* (2017) cautioned against the absence of scientific rigidity of many experiments reported in scientific publications are performed, this therefore precluding strong inference. A review by Treves *et al.* (2016) of publications on predation management in North America and Europe found that very few of the experiments that have been conducted in these publications conformed to rigorous testing using their so-called "gold standard" for scientific inference (≈ these experiments did not randomly assign control and treatment groups and the experimental designs did not avoid biases in sampling, treatment, measurement or reporting). Consequently, Treves *et al.* (2016) suggested that publications which do not meet the "gold standard" should be disregarded when predation management tools are designed or implemented. It is however important to acknowledge that, although peer-reviewed information is not flawless in many cases, it is the most reliable information to base current understanding of a specific topic upon (NRC 2004).

However, based on what scientific evidence is available, we are able to conclude that (but see Treves *et al.*, 2016; Eklund *et al.*, 2017; Van Eeden *et al.*, 2017):

1. The predation management methods employed by a farmer will vary depending on *inter alia* the damage-causing species that is being targeted, the type of livestock operation, season, location, and the environmental conditions (also see Eklund *et al.*, 2017; Van Eeden *et al.*, 2017).
2. Unselective, lethal control (≈ blanket removal of damage-causing species) may be counterproductive in the long term;
3. Unselective, lethal control is generally the most indiscriminate and hence may raise the most ethical and biodiversity concerns amongst stakeholders (also see Chapter 4);
4. Although some predation management methods are expensive to implement (e.g. fencing), it is possible that they may prove very cost-effective techniques in the long term;
5. There is increasing evidence to suggest that certain non-lethal methods (when used in combination) can successfully decrease livestock predation and be cost-effective;
6. Many predators have the ability to become habituated to predation management methods, supporting the concept that a suite of methods should be used and alternated.

Most importantly, it must be acknowledged that predator control does not always equate to predation management. While the former may be effective at reducing predator numbers in an area, in many instances it might not be effective to decrease livestock predation in the long term and also have various negative environmental and ethical consequences. Thus, when predation management is planned, the objective should not be to eradicate all predators in an area because it may not successfully address the problem of livestock predation (also see Eklund *et al.*, 2017). We advocate the livestock owner utilizing a wide variety of complementary strategies (including selective, lethal methods where necessary) in order to protect his/her animals (see Box 6.3). We caution that no single approach should be regarded a panacea for HPC in South Africa and that in most cases additional, applied research of the appropriate scientific standards (i.e. randomised with repeats and controls) is urgently required (see Mitchell *et al.*, 2004; Treves *et al.*, 2016; Eklund *et al.*, 2017; van Eeden *et al.*, 2017; Box 6.5). By their very nature, this may mean that assessments of the efficacy of lethal techniques will require the lethal removal of predators. A careful assessment of local conditions, the cultural and religious context, ethics and the socio-economic position of the landowner(s) is required before any management intervention is prescribed or implemented.

Box 6.5 Knowledge gaps related to predation management in South Africa

There is a general lack of information on the management of livestock predation in South Africa and to a large extent internationally (for both lethal and non-lethal methods) and it is virtually impossible to highlight specific research questions. Considering the large scale lack of information, we envisage that it may be necessary to prioritize research on specific management methods in future (e.g. target specific methods, non-lethal methods, or ethically acceptable methods; see Chapter 4). It is important that this research is of an appropriate scientific standard (i.e. randomised with repeats and controls - see Mitchell *et al.*, 2004; Treves *et al.*, 2016; Eklund *et al.*, 2017; van Eeden *et al.*, 2017). It is also important that this research is done at spatial and temporal scales relevant to the livestock production contexts they are intended to benefit and the species they are suspected to affect.

For each individual method that is studied we recommend focusing on:

1. The effectiveness of the method for decreasing livestock predation, in both the short and long term and preferably in different settings;
2. The cost-effectiveness of the method;
3. The potential environmental and ecological impacts of the method.

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Predators are valued as part of South Africa's natural heritage, but are also a source of human-wildlife conflict when they place livestock at risk. Managing this conflict ultimately falls to individual livestock farmers, but their actions need to be guided by policy and legislation where broader societal interests are at stake. The complexity of the issue together with differing societal perspectives and approaches to dealing with it, results in livestock predation management being challenging and potentially controversial.

Despite livestock predation having been a societal issue for millennia, and considerable recent research focussed on the matter, the information needed to guide evidence-based policy and legislation is scattered, often challenged and, to an unknown extent, incomplete. Recognising this, the South African Department of Environmental Affairs together with the Department of Agriculture, Forestry and Fisheries, and leading livestock industry role players, commissioned a scientific assessment on livestock predation management. The assessment followed a rigorous process and was overseen by an independent group to ensure fairness. Over 60 national and international experts contributed either by compiling the relevant information or reviewing these compilations. In addition an open stakeholder review process enabled interested parties to offer their insights into the outcomes. The findings of the scientific assessment are presented in this volume.

"Livestock Predation and its Management in South Africa" represents a global first in terms of undertaking a scientific assessment on this issue. The topics covered range from history to law and ethics to ecology. This book will thus be of interest to a broad range of readers, from the layperson managing livestock to those studying this form of human wildlife conflict. Principally, this book is aimed at helping agricultural and conservation policymakers and managers to arrive at improved approaches for reducing livestock predation, while at the same time contributing to the conservation of our natural predators.

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